ELECTROMECHANICAL

components & systems DESIGN

AUGUST
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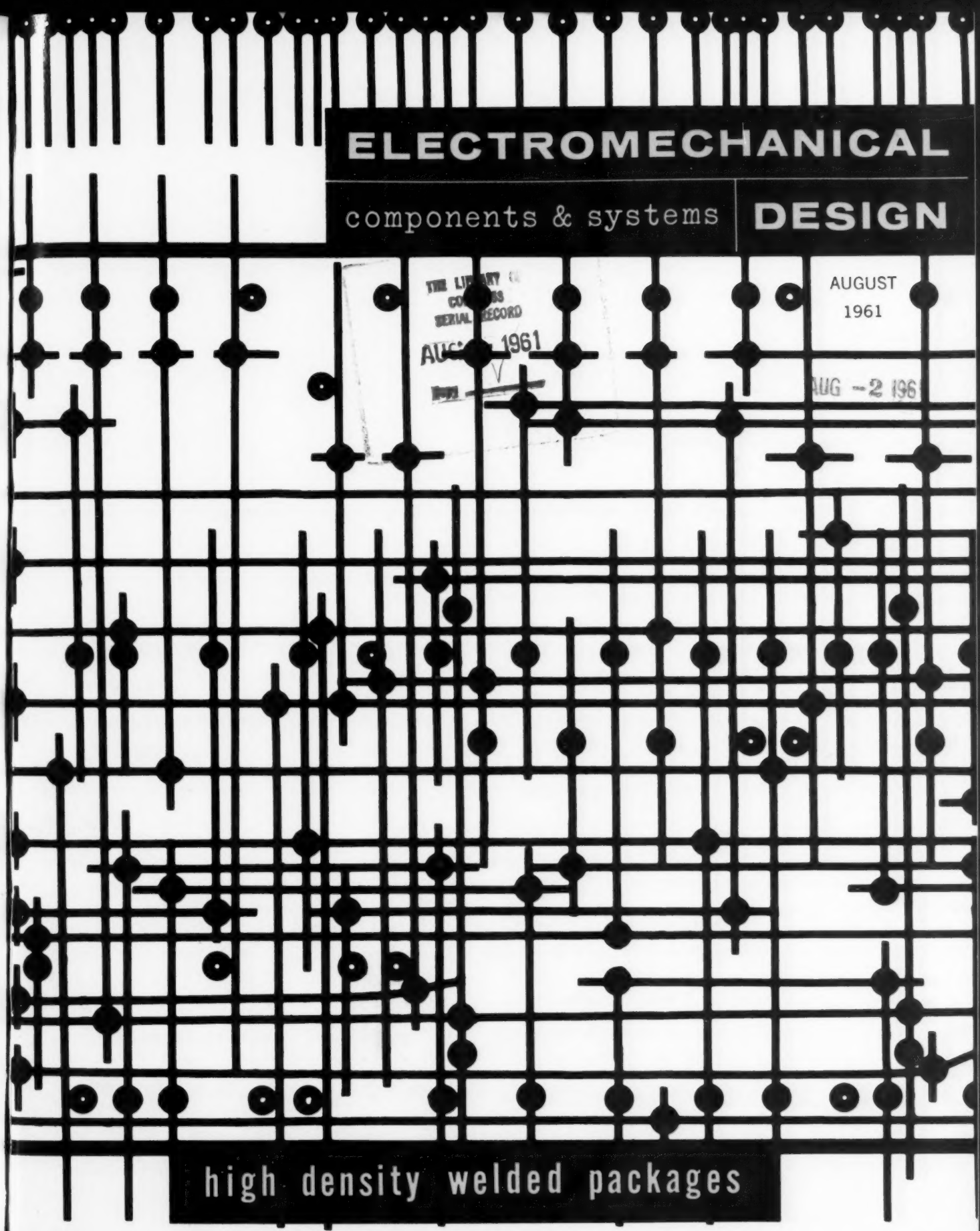


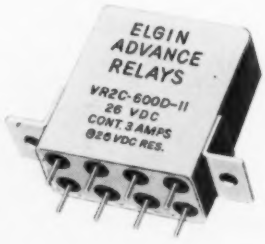
high density welded packages

35G VIBRATION RELAY

A SENSITIVE RELAY WITH 0.2 INCH GRID SPACED TERMINALS

SPECIFICATIONS:

Contact Arrangement: DPDT (2C)
Contact Rating: 3 amps resistive at 28VDC
Operating Power: 250 MW standard, 100 MW special
Vibration: 35G's to 3000 CPS
Shock: 100G's standard, 150G's special
Dielectric Strength: 1000V RMS, 750V RMS between open contacts
Ambient Temperature Range: —65°C to +125°C
Terminals: plug-in pins, solder hooks, 3-inch leads
Mounting: a variety of popular bracket and stud arrangements
Dimensions: 0.875 inches high, by 0.800 inches wide, by 0.396 inches thick
Weight: 0.6 ounces maximum



VR SERIES RELAY

ELGIN advance RELAYS

THE ELECTRONICS DIVISION OF ELGIN NATIONAL WATCH COMPANY
2435 NORTH NAOMI STREET, BURBANK, CALIFORNIA

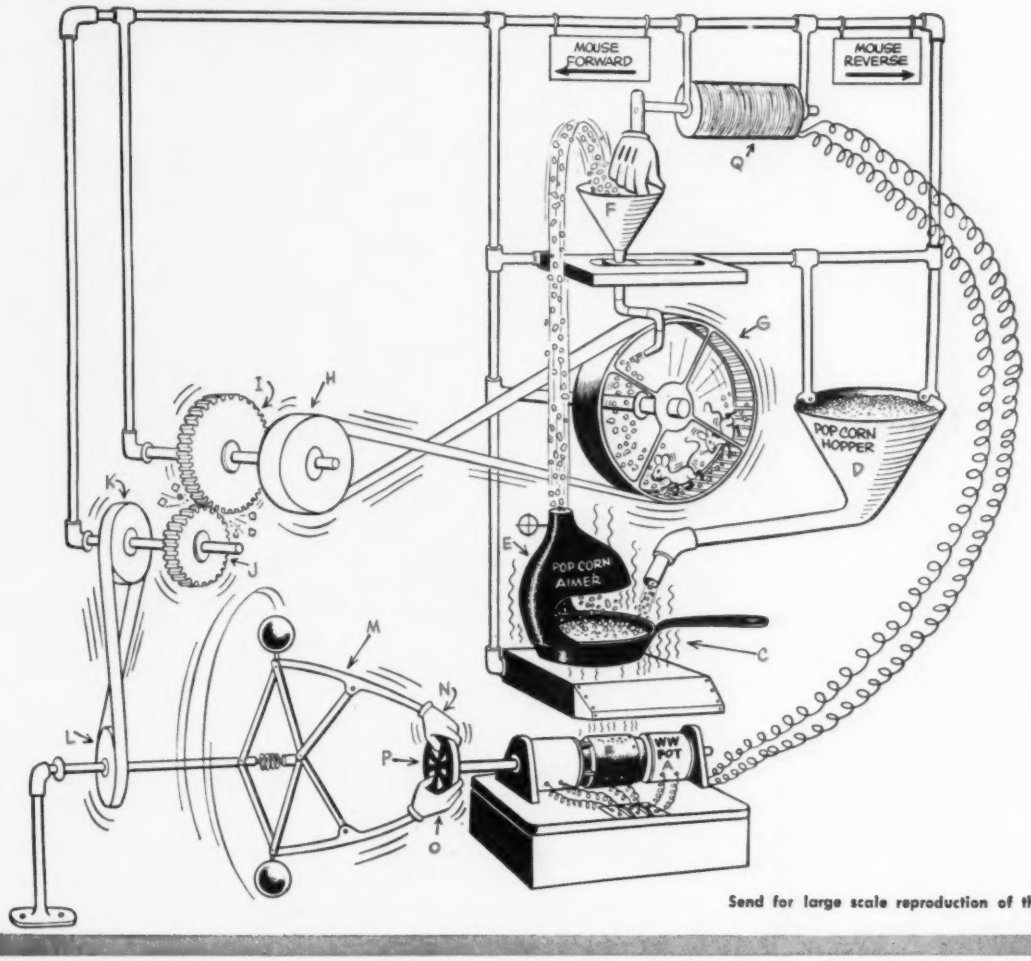
ELGIN ADVANCE RELAYS

SEND FOR LATEST DATA

SEE THIS AND OTHER NEW PRODUCTS AT WESCON BOOTH 1802-04

CIRCLE NO. 1 ON INQUIRY CARD

How To Improve Response Speed of Servos Using Wire-Wound Pots...



Send for large scale reproduction of this unique system.

High starting torque Wire-Wound pot (**A**) stalls Servo Motor (**B**). Motor overheats. Frying Pan (**C**) becomes hot and proceeds to pop corn. (Note Popcorn Hopper (**D**) designed for slow, continuous flow of top quality corn.) As corn pops, Turbo Jet Popcorn Aimer (**E**) directs stream of popped corn to Funnel (**F**). Corn is then directed into Auxiliary Power Treadmill (**G**), causing popcorn-loving mice to start Power Treadmill revolving as they begin to chase falling popcorn. Revolving Power Treadmill then turns Pulley (**H**) which turns Gears (**I** & **J**), in turn revolving Pulleys (**K** & **L**). Pulley (**L**) spins Fly-Ball Governor-Grabber (**M**). As momentum is increased Governor-Grabber causes spinning Clutch-Hands (**N** & **O**) to engage Wheel (**P**), supplying the additional torque necessary to start servo rotating.

Reversing input signal flips Solenoid (**Q**) to reverse position, sliding Funnel (**F**) to Mouse-Reverse position. As popcorn is then directed into other side of Power Treadmill, the mice reverse their running action so as to continue catching falling popcorn. Periodic replacement with fresh mice and/or use of cheese-flavored popcorn can be used to increase efficiency of this system.

BUT THE BEST WAY YET... Use **C.I.C.** Low-Torque Film Pots!

Low torque is an inherent property of C.I.C. Film Pots. The smooth, unbroken, mirror-like surface of film offers minimum friction to the wiper and requires low brush pressures for continuity. As a result, C.I.C. Film Pots have multi-million cycle life.* Write for your free C.I.C. catalog facts today.

*Ask for list of missiles and aircraft currently using C.I.C. Film Pots.

- INHERENT RELIABILITY
- INFINITE RESOLUTION
- PRECISION LINEARITY
- MULTI-MILLION CYCLE LIFE
- LOW OPERATIONAL NOISE
- VIDEO FREQUENCY OPERATION

COMPUTER INSTRUMENTS CORPORATION

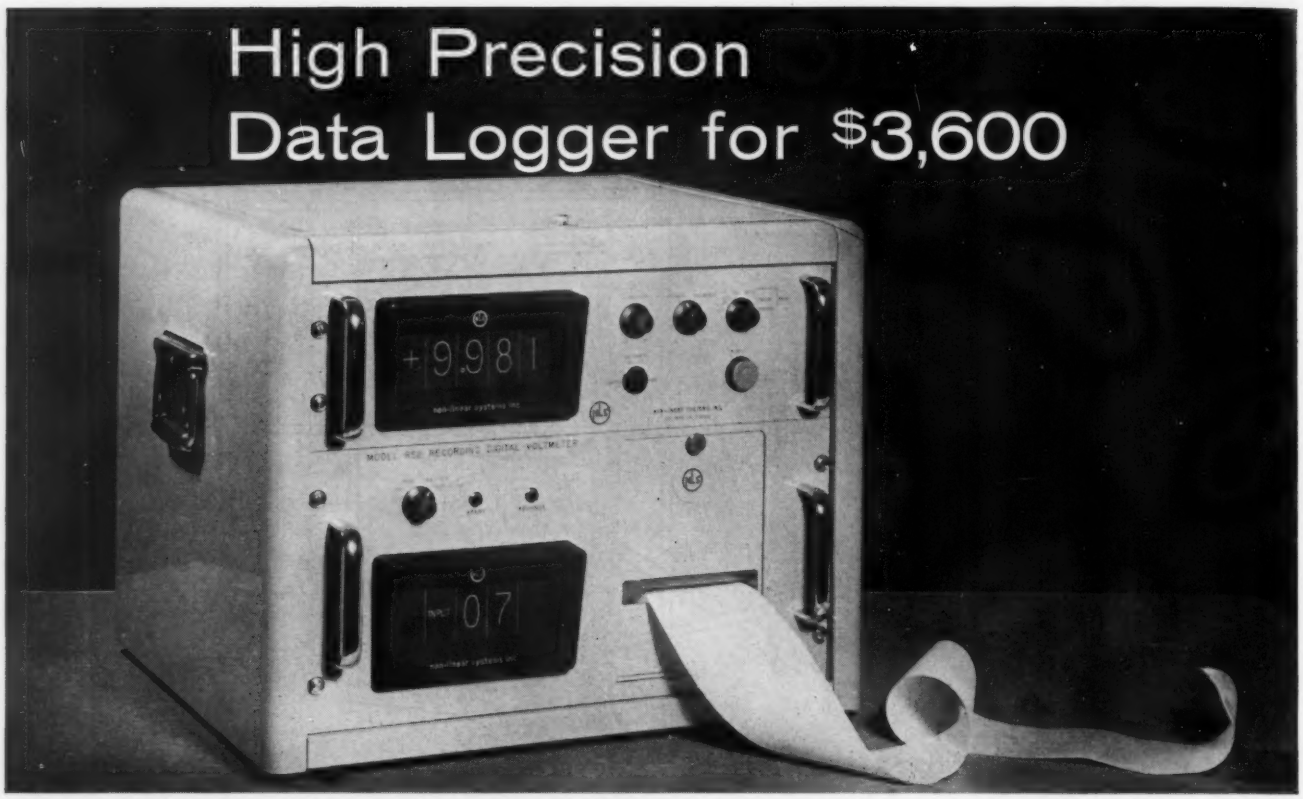
92 MADISON AVENUE • HEMPSTEAD, L. I., NEW YORK

"first in film pots"

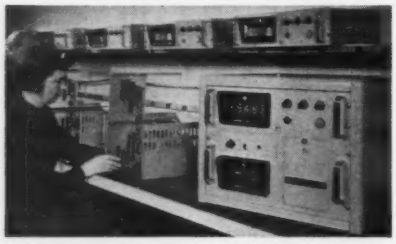
CIC

CIRCLE NO. 2 ON INQUIRY CARD

High Precision Data Logger for $3,600

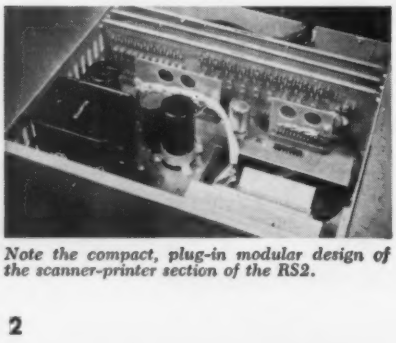


The RS2 Recording Digital Voltmeter – now in volume production at Non-Linear Systems, Inc. – scans up to 20 double-pole input channels . . . measures DC voltage from ±0.001 to ±999.9 with ±0.01% accuracy . . . and records input channel number and the 4-digit voltage measurement. Uses include research and development, quality control, environmental and reliability testing.



Volume production and simplified controls of the RS2 account for its low cost – half to a third less than custom-built units.

Plug-in stepping switches in the digital voltmeter section of the RS2 permit replacement of all switches and decade resistors in minutes instead of days.



Note the compact, plug-in modular design of the scanner-printer section of the RS2.

NLS Reports on Low-Cost, Standard Data Logger

A low-cost automatic data logger built as an integrated scanning, measuring and printing system – the RS2 Recording Digital Voltmeter – is now in volume production at Non-Linear Systems, Inc.

This economy-priced NLS logger is designed for applications requiring high accuracy and low cost without need for the higher speed and greater input capacity of higher cost NLS systems. Simplified controls offer several automatic and manual modes of operation to meet the needs of a great number of applications.

While utilizing many circuits field-tested for six years in thousands of NLS digital voltmeters, the RS2 has undergone extensive testing as a standard, complete system. It is delivered ready to use, without need for additional engineering or complex interconnections.

Call your NLS regional office or representative for a demonstration, or write NLS.

SEE THE RS2 AT WESCON, BOOTHS 1518-1520

RS2 BRIEF SPECIFICATIONS

Visual Indication: 4-digit voltage reading with correct polarity and range. 2 digits for input channel identification.

Range-Polarity Indication: automatic

Functions: scanning up to 20-double-pole channels; measuring DC voltage from ±0.001 to ±999.9 in ranges of ±9.999/99.99/999.9; printing channel number, 4-digit reading, polarity and decimal point placement.

Accuracy: ±0.01% of full scale on each range.

Speed: 2 seconds average for each data point scanned, measured and recorded.

Scanner Operation Modes: AUTO CYCLE – system continually repeats automatic scanning cycle from channel 00 to 19. ONE CYCLE – system automatically stops after scanning channel 19. PRINT – one input is measured without advancing scanner. Scanner may be manually advanced one channel at a time by depressing front panel ADVANCE button.

AC Voltage: Use NLS AC/DC Converter.

Low-Level DC: Use NLS Model 140 Preamplifier.

Input Impedance: 10 megs on all ranges.

Size: 14" high, 15¼" deep for 19" rack.

Delivery: From stock. 30 days, maximum, should stocks become depleted.

Originator of the Digital Voltmeter

non-linear systems, inc.

DEL MAR, CALIFORNIA

CIRCLE NO. 3 ON INQUIRY CARD

ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

AUGUST 1961 • VOL. 5 NO. 8

Contents

COMPONENTS DESIGN

12 SOFT SEATS FOR HIGH PRESSURE
Anti-dribble, Bubble Tight Closure for High Pressure, High Flow Valves

14 THERMOELECTRIC GENERATOR
Isothermal Hot Rod, Key to Optimum Performance

16 NOISELESS TIMING MOTOR
Lifetime Continuous Operation from Spring Loaded Packing Gland

SYSTEMS DESIGN

20 RADIO TELEMETRY REPLACES SLIP RINGS
Miniature Multichannel FM/FM Systems With High Signal-to-Noise Ratio Transmit Low-Level Test Signals From High Speed Shafts

NEW TECHNIQUES

24 HIGH DENSITY WELDED PACKAGES
Welded Cordwood Packaging Technique as Used in Polaris Digital Computer Extended to Analog Systems Applications

32 PELTIER COOLING OF HOT SPOTS
Heat Conduction of Ordinary Copper Shown to be Superior to Thermoelectric Materials for Hotspot Cooling

DESIGN TIME SAVER

34 INSTRUMENT BALL BEARING SELECTION
Factors to Consider in Order to Take Full Advantage of Bearing Reliability

MANAGEMENT

38 HOW NEWTON DISCOVERED THE LAWS OF GRAVITATION
A Walk in the Garden Just Before a Meeting of the Committee to Combat Opium Eating Among Students Without Nobility

COMPONENTS DIGEST

43 MOTOR-DRIVEN TIMING DEVICES – COMPONENTS DIGEST 20, PART III
Output Mechanisms, Timing Cycles, Complex Devices, Commercially Available Units

DEPARTMENTS

61 MAGNETIC CLUTCHES & BRAKES – COMPONENTS DIGEST 13, PART II
Industrial Units

6 PUBLISHER'S PAGE

66 NEW COMPONENTS FOR ELECTROMECHANICAL SYSTEMS

77 CONTRACTS

78 NEW CATALOGS FOR YOUR LITERATURE FILE

79 DATA SHEETS FOR YOUR THREE RING BINDER

80 INDEX TO ADVERTISERS

82 PRODUCT INDEX

BPA Circulation for August over 29,000

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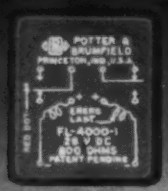
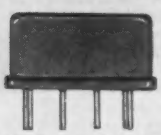
a New and superior latching P&B relay



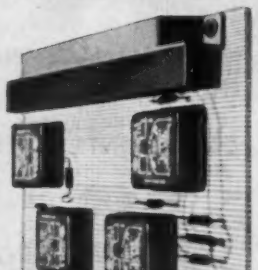
LIES FLAT FOR GREATER PACKAGE DENSITY, HIGHER PERFORMANCE



This DPDT, permanent magnet, latching relay is superior on these counts: (1) shorter height for maximum compactness between stacked circuit boards; (2) greater sensitivity (80 milliwatts); (3) better vibration resistance (30 g to 2000 cps); (4) better shock resistance (100 g).

Designated the FL Series, this relay meets all applicable sections of MIL-R-5757D, MIL-R-6106C and ABMA #PD-R-187.

Call your nearest P&B representative today for complete information about the whole P&B family of microminiature relays.



Printed circuit board using 4 FL relays was designed by the Martin Company, Orlando, as part of ground support equipment for a major missile project.

FL SERIES SPECIFICATIONS

Contact Arrangement: DPDT

Shock: 100 g for 11 milliseconds with no contact openings.

Vibration: .195" max. excursions, 10 to 55 cps. 30 g from 55 to 2000 cps. No contact openings.

Linear Acceleration: 400 g minimum with no contact openings.

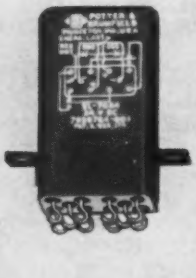
Pull-In: 150 milliwatts, approx. (standard) at 25°C. coil temperature.

80 milliwatts, approx. (sensitive) at 25°C. coil temperature

Operate Time: 3 milliseconds max. at nominal voltage at 25°C. coil temperature

Dimensions: .485" high, 1.100" long, .925" wide

THERE'S A P&B CRYSTAL CASE RELAY FOR YOUR PROJECT



Diode in relay case is used for arc suppression in special applications. Four diodes form full-wave bridge rectifier for 400 cycles.

Non-latching or latching relays in conventional crystal cases with or without shoulder brackets, studs or mounting plates. All types of terminals are available.

Terminals spaced on .200" grids are available on all P&B microminiature relays. These carry a "G" suffix (SCG and SLG) and are .890" high, .800" wide, .400" deep, max.

These 3 relays are shown slightly reduced in size.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONICS PARTS DISTRIBUTOR

POTTER & BRUMFIELD

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IN CANADA: POTTER & BRUMFIELD, DIVISION OF AMF CANADA LIMITED, GUELPH, ONTARIO

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components & systems DESIGN

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← CIRCLE NO. 4 ON INQUIRY CARD

For overcurrent protection that fits hand-in-glove with tight operating specs, try the Heinemann Type C Overload Relay. You can practically design it yourself, to your particular requirements. And at reasonable cost. You not only can specify the exact integral or fractional continuous-duty current rating you need (between 0.02 and 60 amps), you can spec response characteristics, too. Within broad overall limits, you can have the precise time-delay-vs-overload action you want. All you have to tell us is the time within which actuation must occur at any specified overload value. In most cases, this value can be as low as 115% rated load. (Because the Type C is magnetically actuated, the calibrated trip points you select will remain constant for the life of the relay—no ambient-temperature compensation is necessary.) ■ Optionally available with trip indication and lock-out features, the Type C Relay is fully described in our Bulletin 5103. Write for a copy.

HEINEMANN ELECTRIC COMPANY, 125 BRUNSWICK PIKE, TRENTON 2, N. J.

SA 2389

CIRCLE NO. 5 ON INQUIRY CARD

Publisher's Page

GENTLEMEN'S AGREEMENT?

There's a movement afoot to limit the usefulness of Wescon and IRE to the point where attendance will hardly seem worthwhile. Somehow, Wescon and IRE officials became convinced that the prime purpose of these conventions was to present papers and peddle products. In line with this belief they're urging – through a "gentlemen's agreement" – that no recruitment practices take place at the Shows. No doubt they were motivated by nothing but the best interests of the exhibitors; but there is also no doubt that fulfillment of this gentlemen's agreement could be more of a detriment than an asset.

It pays to re-evaluate original objectives of any organization five, ten or fifteen years after its inception. Often secondary activities eclipse the founding objectives because of growth and changing patterns within an industry or economy. We're guessing that in addition to earning money for the sponsors of Wescon and IRE, its other founding goals were to spark engineers to the solution of their engineering problems, to promote the profession of the engineer in general and to assist corporations in spreading the word about their products and services. But Wescon and IRE now offer an equally important fringe benefit to companies and engineers: keeping up-to-date with living costs, salaries and job opportunities throughout the United States. Let's take a closer look at this generalization.

Most engineers have limited opportunities to travel, become familiar with living in other states, and learn, first-hand, of career prospects at myriads of companies. How much job-hopping results from making decisions before investigating more thoroughly available opportunities at the time of the move? Wescon and IRE give engineers a "feel" for employment in a way that perhaps no other activity could possibly achieve in the same short period of time at such small cost.

Mature engineering management recognizes that engineers on their staff can become restless for any one or more of many reasons: their interest in a particular field lags; they feel their opportunities for advancement are limited; expanding markets and new engineering disciplines seem to offer more opportunities for professional and economic growth; or they may just feel that they've had it in a particular company for personal or professional reasons. Disaffection with employment – whatever the reason – is never solved by ignoring it. Engineers who are constantly exposed, without prejudice, to opportunities for improving themselves always make better contributions to the corporations in which they are employed. Disaffected engineers do not have reputations for producing creative work; faster they either decide to stay or leave benefits them and the corporations they work for. Indeed, many management men who, for reasons only known to themselves, cannot give an engineer his dismissal notice send him to Wescon or IRE and hope that the man comes back with notice of his termination.

Engineering management must keep up with market trends in personnel as well as in products. Corporations with an open policy of "if at any time you can better yourself, either professionally or economically, within some other corporate structure, we shall do all in our power to help you" are usually the ones that have the least problems with employees. They have learned that engineers looking for a job surreptitiously cost the corporation time and money. An open attitude helps keep the more mature man who has worked for three or four companies and realizes that political cliques exist everywhere; engineering goals as well as personal ones are beset by compromises; and that a few more bucks is not the sole criterion of a move. Moreover, where but at a Wescon or IRE can management get a fast measure of salary conditions and job opportunities existing in ten or fifteen states, in twenty or thirty aspects of the industry, so that they can compare what they offer their engineers with what their engineers may possibly be offered by some other corporation?

Our economy depends upon the growth of new companies and new industries, many of which are spawned in the basements and garages of engineers. Wescon and IRE offer these men an efficient and quick way in which they can get together to set up their own business, establish national sales forces and combine engineering talents. How many new industries and new companies were initiated or got their final kick-off at one of these Shows?

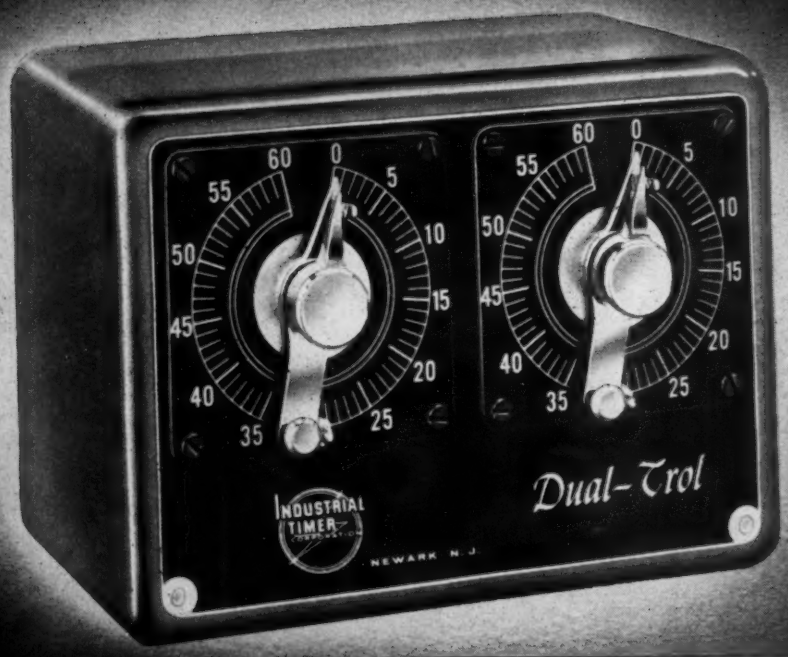
Perhaps the greatest contribution Wescon and IRE make to our corporate organizations is that for every engineer who finds a job at these conventions, there must be hundreds who return to their companies happier and more content with what they hold in their fists and didn't appreciate. In the final analysis, most gentlemen's agreements, shadowing the fringe of legality, have not been in the best interests of individuals or the public. And we add that Wescon's Gentlemen's Agreement is not in the best interest of the exhibitors.

Go to Wescon to present a paper or sell a product only? Hardly worth the time or money; you can sit home and read the papers a lot faster and the equivalent time and money spent in generating sales leads can probably be expended more efficiently elsewhere.

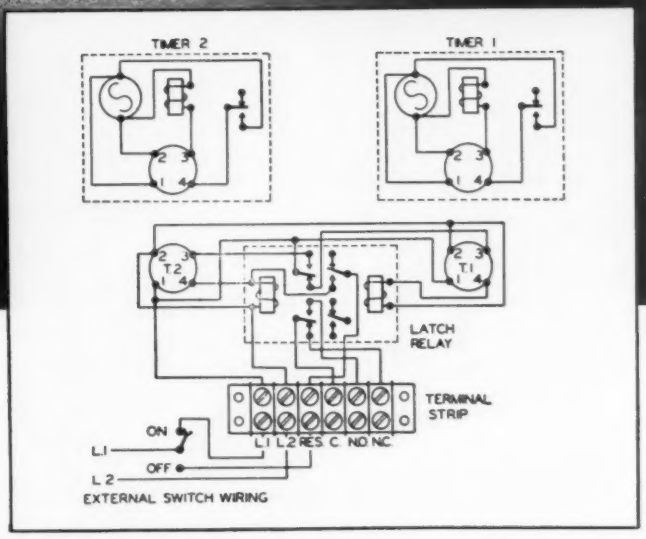
Harold C Buckbinder

Publisher

THIS IS NEW!



INDUSTRIAL TIMER *Dual-Trol* Recycling Timer



Dual-Trol represents a broad new modular concept of automatic timing control far more flexible, reliable, and *practical* than anything before.

It is engineered and designed for easy installation and interchange of ten different modular timer units that can be paired to provide limitless combinations of on-off cycles—from 6 seconds to 3 hours.

Dual-Trol is extremely compact (7½" x 6" x 5") and features isolated load contacts, and adjustable dials for setting the desired on-off sequence.

Get our Dual-Trol Bulletin 501 with the details of this significant new automatic timing device for industrial processes. Simply send the coupon.

INDUSTRIAL TIMER CORPORATION

INDUSTRIAL TIMER CORPORATION

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3 Hamilton Ave., Ottawa, Canada • PA 8-4681

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1405 McCarter Highway • Newark, New Jersey

Gentlemen:
Please send me your Dual-Trol Bulletin 501.

Name_____

Title_____

Company_____

Address_____

City_____ Zone_____ State_____

HOFFMAN ENTERS THE POTENTIOMETER FIELD

SHEDDING NEW LIGHT ON POTENTIOMETER PERFORMANCE

Hoffman now offers a line of precision potentiometers with the highest resolution ever achieved in wirewound units — backed by an outstanding record of company reliability.

WESCON BOOTH 1615

Hoffman / ELECTRONICS CORPORATION
Instrument Division

2621 S. Hill Street, Los Angeles 7, California • Richmond 7-4488

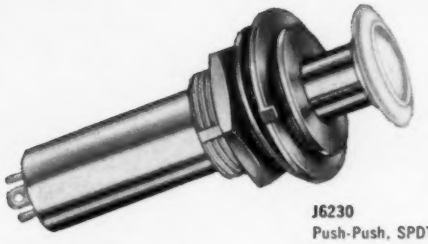
ENGINEERING NEWS - #10

LIGHTED PUSHBUTTON SWITCHES

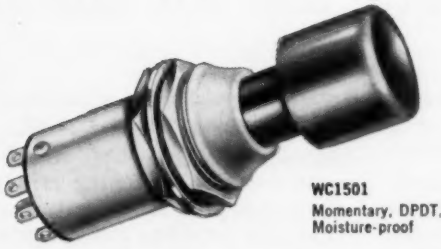
CHECKED *HEd*	ENGR. *W.E.M.*	CONTROL SWITCH DIVISION

A3311
Momentary, N.O., or N.C. (A3312)

A3298
Momentary, SPDT



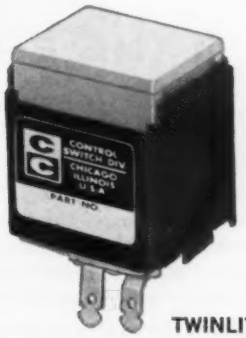
J6230
Push-Push, SPDT



WC1501
Momentary, DPDT, Moisture-proof

These five models indicate only a part of the full line of SWITCHLITES made by Control Switch Division. These units combine both switch and indicator light in a single rugged, compact assembly. They are available with momentary, push-push, or push-pull snap-action, having a positive feel. There are eight basic case styles, 20 circuit arrangements. Switch ratings from 2 to 20 amps, ind. or 10 to 20 amps, res. at 28 VDC—depending on switch type, circuit, and required operating life. Switchlites use a midget flange base MS25237 lamp, 6, 14 or 28 volts. Choose from five styles of plastic pushbuttons in standard transparent and translucent colors.

In other words, almost any requirement you may have for a compact lighted pushbutton is available in a standard SWITCHLITE from Control Switch Division. For more technical data write for free literature.



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Here is a low-cost lighted pushbutton containing two lamps which may be individually circuited. Plastic lens is 1" x .740", and comes in one solid color, two-color split, engraved or with a nameplate slot. Select double-pole or triple-pole switching with push-push, momentary, or solenoid-held action. TWIN-LITE mounts individually with barriers, in rows, or a matrix.

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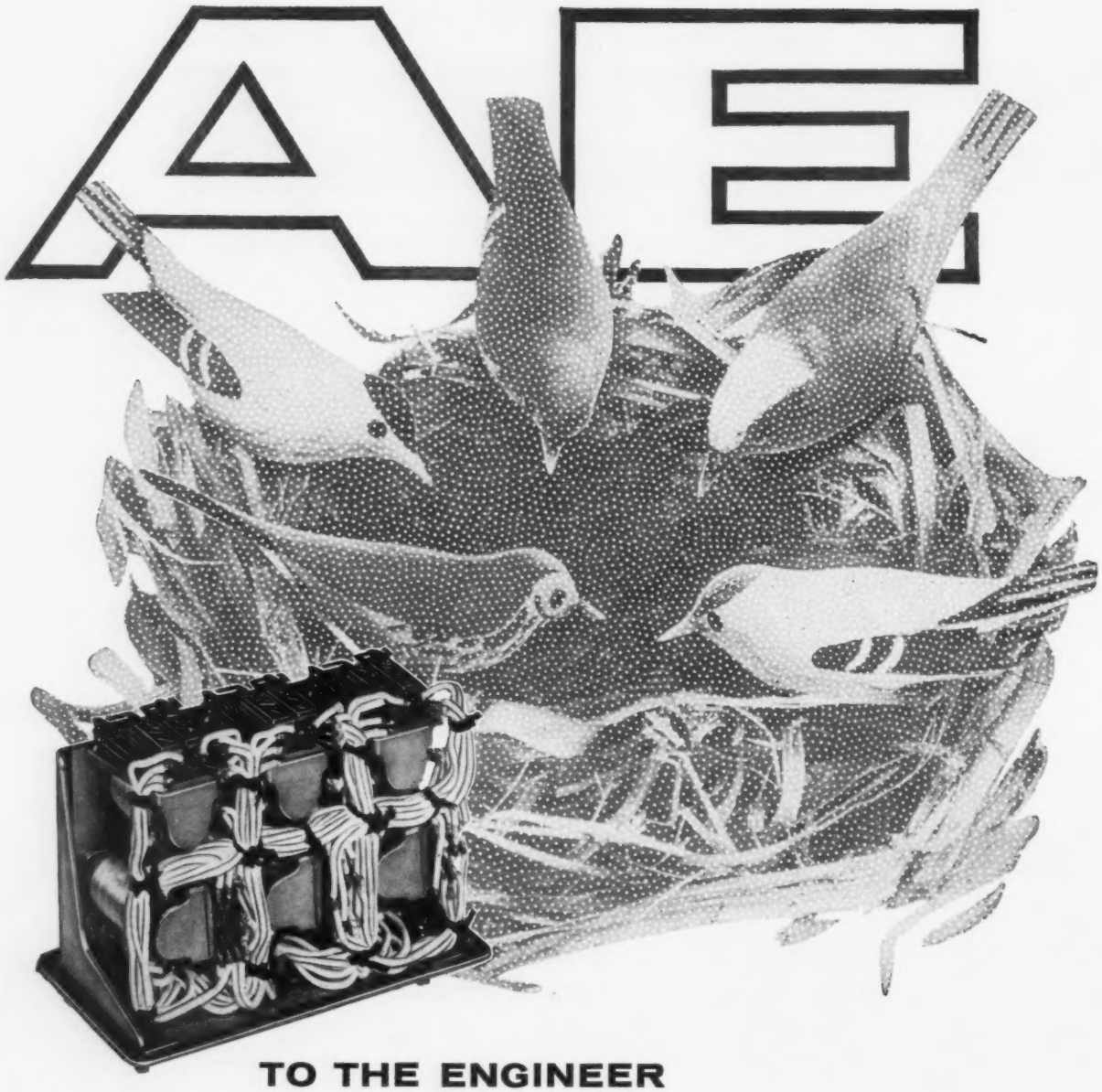
ENGINEERING NEWS -- Lighted Pushbutton Switches



TO THE ENGINEER

who thinks "birds' nests" are for the birds...

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GENERAL SYSTEM

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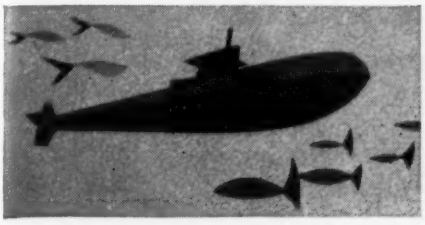

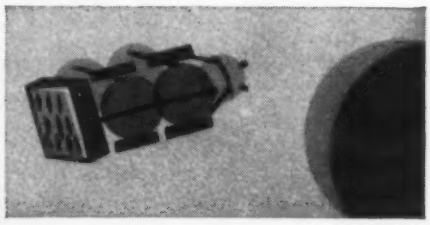

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Vāp-Air Mercs have many uses, widespread acceptance

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Used for:
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have proved outstandingly accurate and dependable for the most critical thermal sensing and control applications in missiles, aircraft, ground support and undersea equipment.

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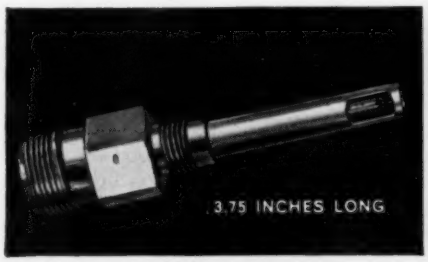

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CIRCLE NO. 10 ON INQUIRY CARD

SOFT SEATS FOR HIGH PRESSURES

Anti-dribble, Bubble Tight Closure for High Pressure, High Flow Valves

If you would question the patentability of the application of a standard O-ring as a valve seat for a variety of poppet configurations, you would be in complete agreement with our editorial staff – and just as wrong. Captive Seal Corporation of Caldwell, N. J. is the holder of the patent in which the valve closure occurs through the axial translation of a plug containing a standard O-ring.

Previously, valves with movable poppet types of closures used semi-hard or hard materials for valve seats and seating bodies. Normally, the higher the fluid pressure, the harder the material. Performance objectives in these designs involved: protection of the sealing member or valve seat from "blow out" during the seating and unseating operation, particularly during high pressure differentials; protection of the sealing members and the poppet from eroding fluid flow; selection of an appropriate material that would not develop a permanent set or deformation as a result of considerable mechanical loading.

Poppet valves that met these service requirements were designs in which a loading force was concentrated on a narrow annular band of contact between the opposing fixed and movable members in such a manner as to develop sufficient contact pressure to prevent the escape of fluid. Practical considerations prohibited a knife-edge sharpness for this narrow band. Better designs contained some effort to pressure-balance the force that could unseat the poppet; this force varied according to pressure, to the amount of seal deformation on the load, and to the extent to which the seats were machined or reground after service.

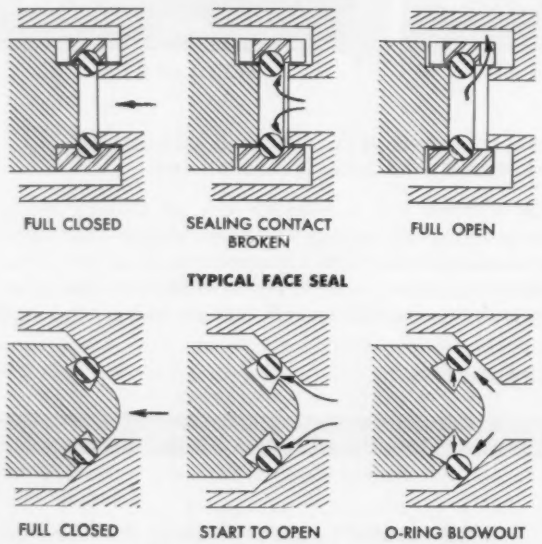


Fig 1 Main problem in using O-rings as face seals is preventing blow-out under high pressure differentials. Illustration shows how blow-out occurs when pressure can get into an O-ring's seat. Captive Seal's design contains a steel retainer that encircles the ring and prevents expansion from the contained pressure; mechanical stop insures the correct amount of end-squeeze. Symmetrical forces on the O-ring keep it in its retainer.

Resilient materials for valve seats and valve seals for the high pressure valves only presented the "blow-out" problem during seating and unseating operations under high pressures. Very resilient materials aggravated the problem of shifting in sealing diameter due to a larger amount of deformation possible with resilient material. Even in low-to-medium pressure application, where mechanical means can be devised to prevent "blow-out", the resultant unbalance in the pressure-induced forces requires large spring loads and/or actuating loads, thus increasing valve weight, size, power consumption and cost.

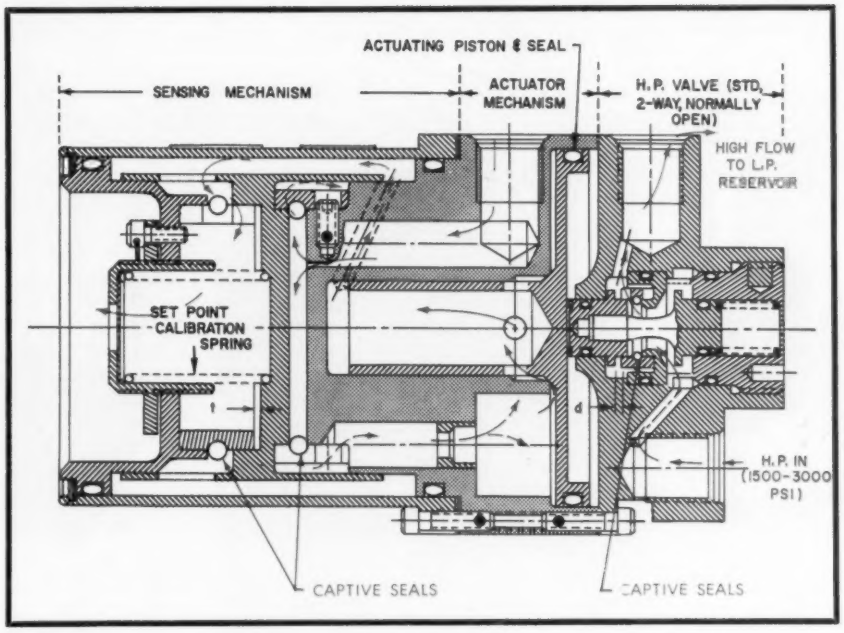
Captive Seal's President, Peter H. Palen, came up with a design for balancing pressure-induced axial forces on a poppet regardless of pressure, and means for using a resilient or flexible seal element that can't blow out during seating and unseating operations (see Fig 1). Here are the advantages Mr. Palen claims for his Captive Seal O-ring type of closure:

- The soft-seat design gives a bubble-tight seal throughout the life of the closure, in spite of contamination in the fluids; it does not require forceful retention to prevent blow out under high pressure service conditions because the seal is pressure-balanced and is under no unbalanced forces during surges of pressure.
- The fixed sealing diameter is independent of fluid medium and pressure and of the elastomer material. Therefore, poppet assemblies can be exactly balanced under all pressure conditions.
- A low seating force maintains sealing effectiveness making poppet action accurately responsive to line pressure and sealing effectively up to a desired actuation pressure.
- Because the seat is a relatively inexpensive standard O-ring instead of a precision machined valve seat, initial fabrication cost is low and maintenance is simple and inexpensive.
- The flexibility of the design can accommodate in one basic assembly as many different fluids as there are suitable elastomers for use as O-rings.

Captive Seal, according to Mr. Palen, plans on applying this type of valve seal and seat to pressure switches, solenoid valves, pressure-responsive valves (relief, sequence), manual valves, double-acting pyro-technic valves, sliding-sleeve balanced industrial valves with low force actuators and other areas in which this new approach can be utilized. Here's an inflation valve design currently in production which incorporates both the high pressure, high flow mechanism and a low pressure responsive element.

INFLATION VALVE

One of the problems presented to Captive Seal involved



LEGEND

In the sensing and actuator mechanisms:

- Solid arrow indicates inflated "article" pressure (low pressure).
- Dashed arrow indicates low pressure flow path after shut-off point has been reached and sensing piston has traveled distance *t*; and actuating piston has also moved distance *d* (pushing on poppet through shim).

NOTES

- Ratio between "actuated" and "reset" pressures (high and low points for inflated "article" pressure) is determined by area ratio of "inflow" to "outflow" Captive Seals on sensing piston.
- Minimum cycling time is roughly 150 milliseconds. (This limits minimum size of inflated article to approximately one cu ft without overshoot for this particular design.)

Fig 2 Captive Seal's Inflation Valve Model 65M190 regulates pressure by an on-off cycle that comes on at 3.75 psig and cuts off at 4.25 psig. Valve assembly contains two elements: a balanced poppet-type, 2-way, normally-open valve that receives pressure from a supply cylinder at 3000 psi maximum storage pressure; the second element, a sensing and motor unit causes the 2-way valve to open fully during the demand cycle or close fully when the maximum inflation is reached.

applying air from a high pressure source to an inflatable article; the inflated article would descend from an altitude of approximately 15,000 ft. to ground level during which the valve was required to maintain a 4 lbs. per square inch gauge pressure ± 0.25 psig during the descent. Means of accomplishing the pressurization could not use any external source of power, had to be self-regulating and respond only to the pressure differential between the interior of the inflated article and the ambient atmospheric pressure. Following a high initial inflation rate, subsequent replenishment had to provide a clean cut off when the maximum of inflation pressure is reached. Furthermore, inflation time was critical as well as system weight and size. Unusual shock requirements had to be met with other extremes of environment.

Fig 2 illustrates Captive Seal engineers' approach to this problem. The method they considered most suitable to achieve the pressure regulation was a step function cycle that cut off at 4.25 psig and then recycled at 3.75 psig. Valve assembly contained two elements: a balanced poppet-type, 2-way, normally-open valve that receives pressure from a supply cylinder at 3,500 psig storage pressure; the second element, a sensing and motor unit, causes the 2-way valve to be fully opened during the demand cycle or fully closed when the maximum inflation pressure is reached. The off-cycle is accomplished with snap-like over-center action; the sensing piston opens rapidly and re-seats immediately on the vent seat causing the full 4.25 psig to be impressed upon the actuating piston which, in turn, closes the 2-way valve without inertia effects.

Recycling for make-up air consists of a complete re-open and re-close sequence. When the inflated article is small in volume, the recycling time becomes extremely short, down to a minimum response time in the order of 150 milliseconds. In such instances, the size and length of the feedback or sensing line, from the inflated article to the valve, becomes an important design criteria in minimizing lag time.

The basic concept of valve closure as developed by Mr. Palen is a flexible one, applicable to a variety of valve configurations, flow control and pressure sensing problems.

While Captive Seal's primary effort has been in solving problems for the military, they believe that the basic simplicity and ruggedness of the design coupled to its low maintenance and valve seat replacement cost make it worth while for applications varying from industrial valving to the faucet in the home. • • •

Write No. 260 In Box on Inquiry Card

Fig 1 Thermoelectric couple is the basic building block of Westinghouse Electric's hot rod generator.

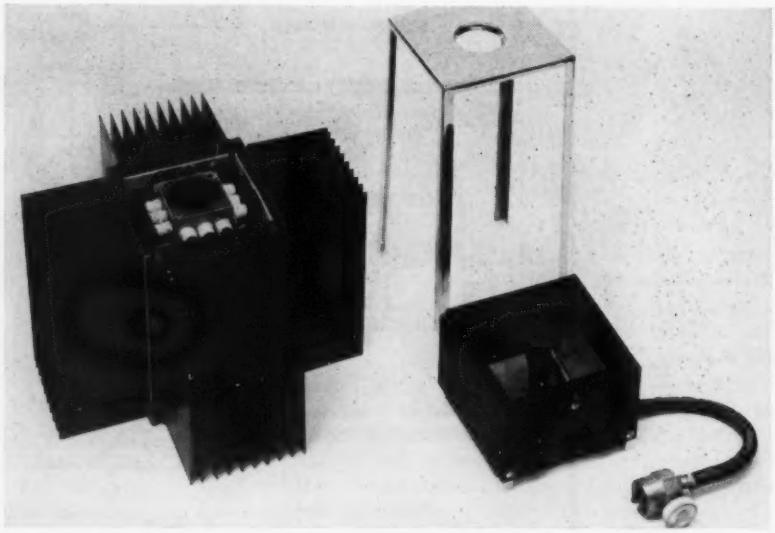


Fig 2 Typical thermoelectric generator disassembled to show: at left, the main unit with rectangular hot rod core and thermocouples between the core and the heat exchanger fins; at right, the burner and base assembly and the cover frame.

THERMOELECTRIC GENERATOR

Isothermal Hot Rod, Key to Optimum Performance

Problems in designing thermoelectric generators can be divided into three main categories:

Structural considerations

Electrical and thermal insulation

Thermal contact and heat rejection

P. E. Pityk and T. M. Corry of Westinghouse report on how they handled these problems in the design of their hot rod thermoelectric generator.

At the very beginning of the design, the Westinghouse engineers decided that it would be advantageous to have all thermoelements operating at the same hot side temperature, T_H, and the same cold side temperature, T_c. In order to achieve this condition, the hot core and heat exchanger must have isothermal surfaces. Once this was accomplished, hot and cold side temperatures could be selected that would produce optimum performance of the thermoelements. In addition, all of the elements would be operating at the same Carnot efficiency.

The thermoelectric couple was chosen as the basic building block. Fig 1 shows a typical couple consisting of a hot strap, *P* and *N* legs, and flexible copper braids. These couples require a structure that will support them and at the same time provide the proper hot side temperature, T_H, and cold side temperature, T_c, without excessive heat leak from T_H to T_c. Fig 2 is a disassembled view of a typical generator showing the couples placed against the rectangular core. Heat exchangers, which consist of cooling fins bonded to four rectangular plates, are fastened together to form a shell around the couples. Thus a structure is formed, using spring compression of the couples for rigidity and support, with no mechanical connection between core and heat exchanger.

Since the couples are in compression between the core and heat exchanger, and are connected electrically in series, Pityk and Corry had to provide electrical insulation on the surfaces of the core and heat exchanger that come in contact with the metallic straps of the couples. They solved this problem by electrochemically coating the core and heat exchanger with ceramic materials. Since there is no mechanical connection, the only heat leaks, which had to be minimized, were due to convection and radiation in the space not occupied by the couples. They took care of this problem by couple density on the core and by filling the space not occupied by the couples with thermal insulation.

Thermal drops had to be minimized since excessive drops between the couple straps and both the core and heat exchanger reduce the available temperature drop across the couples which, in turn, reduces efficiency and power output. To reduce these drops, the designers placed films of high tem-

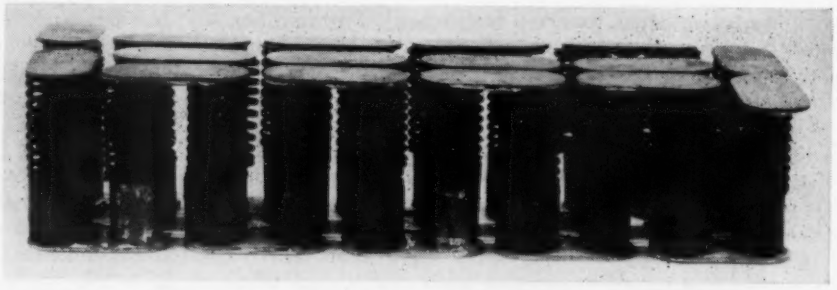


Fig 3 Presassembled thermoelectric ladders containing the thermocouples. Four of these ladders are pressed against the insulated core.

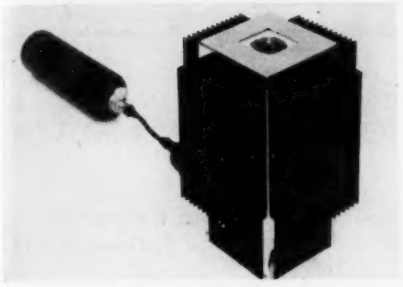


Fig 4 Depending on the hot side temperature selected, approximately 5 to 75 watts can be obtained from Westinghouse Electric's hot rod thermoelectric generator. At a T_H of 550°C and propane as the fuel, for example, the generator delivers approximately 65 watts at a thermal conversion efficiency of approximately 7.3%. Taking into account the burner efficiency, generator provides 258 watt-hours of energy per pound of fuel so that 6 pounds of fuel provides 65 watts for a period of 24 hours of unattended operation.

perature compounds between the straps of the couples and the walls of the heat exchanger.

The thermocouples are encased in pre-assembled, flexible thermoelectric ladders, shown in Fig 3. Pressed against the insulated core, four ladders are connected electrically in series and the output is taken from the four ladders as a unit. These spring-compression ladders allow the generator to expand and contract without causing deterioration in efficiency or permitting severe tensile or shear stresses to appear across the thermoelements.

Since a minimum size and weight was one of the objectives, a free convection heat exchanger had to be developed that could dissipate the highest possible watts per unit weight and per unit area of base plate within reasonable occupied volume. The Westinghouse engineers constructed and tested exchangers including straight, solid-fin, round-pin and rectangular-pin types. They found, from experimental data, that the rectangular-pin type exchanger had the best heat dissipating capability.

Pityk and Corry characterized their final design, shown in Fig 4, as a lightweight, portable generator for use in many military and industrial applications. Weight of the generator is slightly less than 15 lbs. Power output capabilities approach 70 to 75 watts giving a ratio of 5 watts per pound of generator weight. One of the main advantages of this generator is that it is not limited to any particular fuel and a wide variety of fuels such as alcohol, kerosene, gasoline, propane, natural gas or radioisotopes can be used. • • •

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BONDED SILASTIC ACTUATOR SEAL ...
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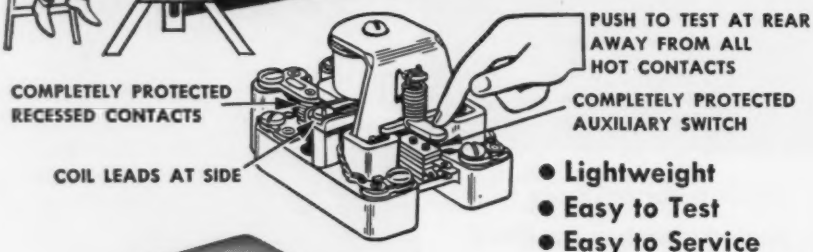
PUSH TO TEST AT REAR AWAY FROM ALL HOT CONTACTS
COMPLETELY PROTECTED RECESSED CONTACTS
COMPLETELY PROTECTED AUXILIARY SWITCH
COIL LEADS AT SIDE

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- Easy to Test
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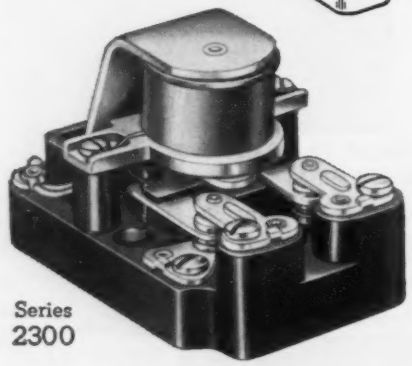
- Easy to Mount



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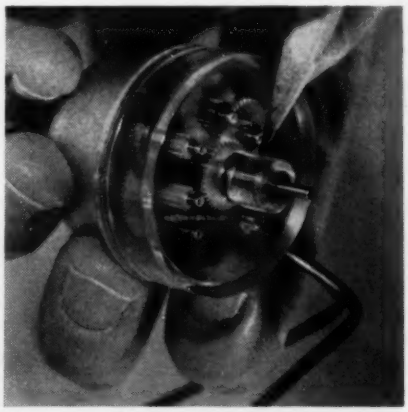

Fig 1 Noiseless oil-filled synchronous timer motor for virtually life-time continuous operation. Spring-loaded packing gland prevents oil from working out of the housing when the motor is operating. Pointer indicates position of the packing gland which is a neoprene "O" ring held under constant pressure by a spring.

According to Ralph L. Berg, president of the company, the new oil-filled motor is expected to have important applications in a broad variety of industrial automation control systems, computers, office equipment, home appliances, and military control devices. The compact new unit conserves precious installation space. Its outside diameter measures only 1-11/16 inches. Other key components of the motor, also submerged in oil, include a variable pole arm which provides starting reliability when rotor poles are stopped at dead center, and a magnetic directional device which maintains proper rotation of the gear when the motor is energized.

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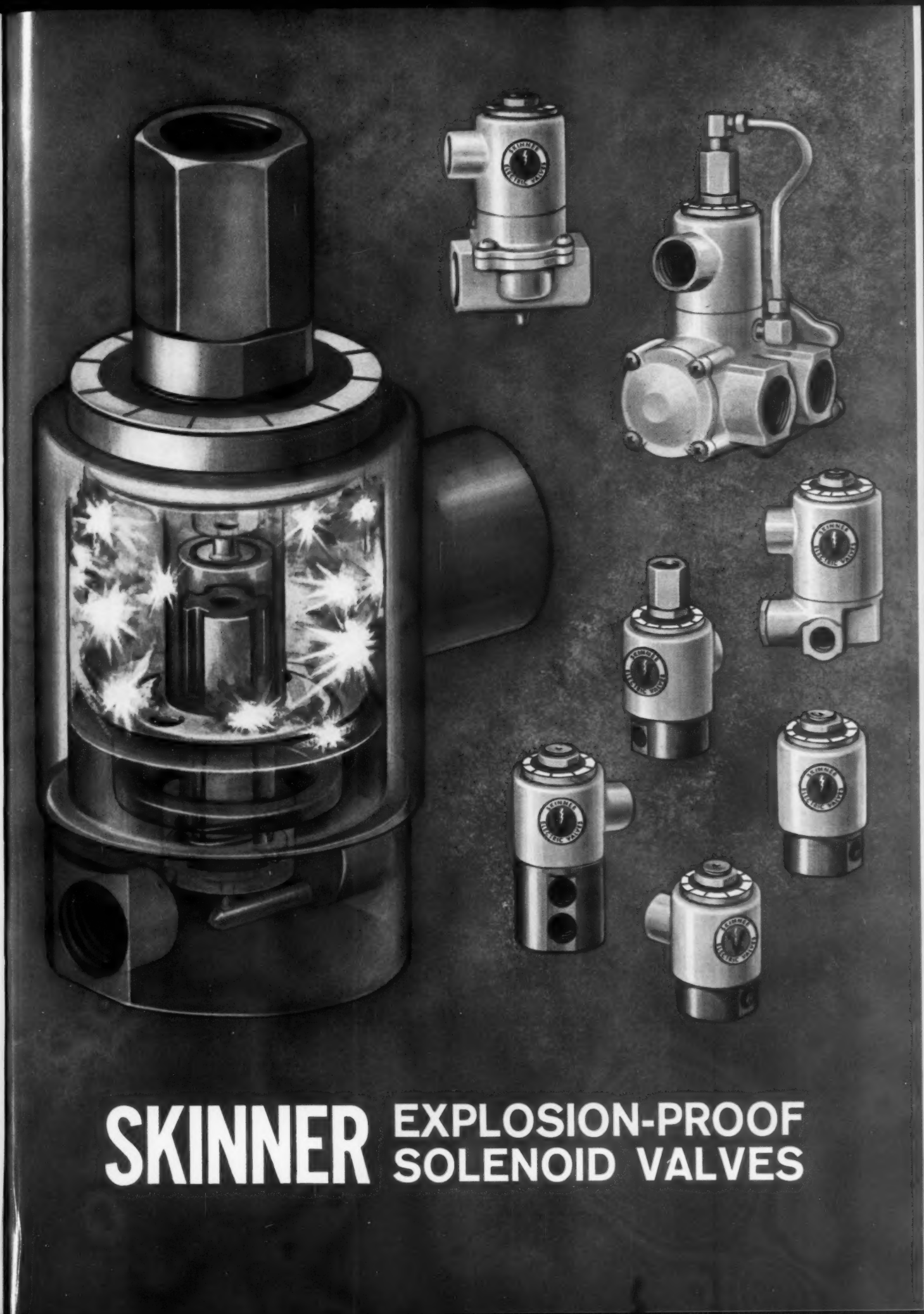
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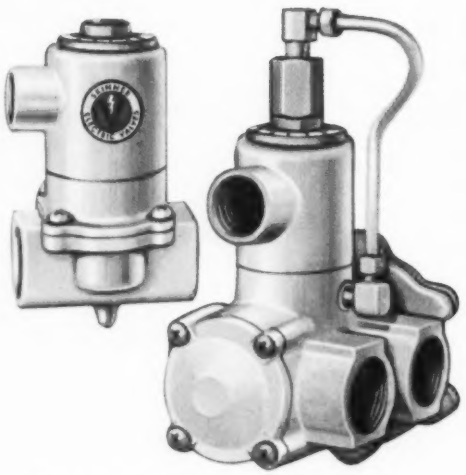

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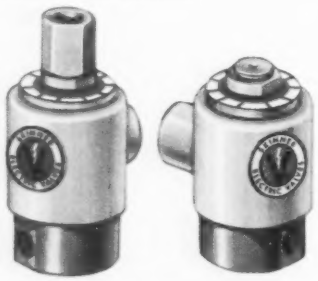
The highest quality and most versatile valves manufactured. So flexible that basic valve can be modified to provide porting, mounting, or flow-control, to meet most applications.

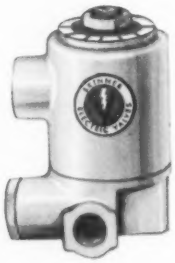


Two-way solenoid valves are available normally closed, normally open and dual purpose. Orifice sizes from $\frac{1}{32}$" to $\frac{3}{8}$", maximum operating pressure differential 3000 PSI depending on orifice size—NPT pipe size $\frac{1}{8}$", $\frac{1}{4}$" and $\frac{3}{8}$".

Three-way available normally closed, normally open, directional control and multi-purpose. Orifice sizes from $\frac{3}{64}$" to $\frac{1}{4}$", maximum operating pressure differential 200 PSI depending on orifice size.

TWO-WAY PISTON TYPE SOLENOID VALVES—XR SERIES

These valves, with forged naval brass body and stainless steel piston, handle high flow and high pressure requirements of industrial and commercial applications with most common media.



XR series valves are available with $\frac{1}{4}$" orifice and $\frac{1}{4}$" NPTF in normally closed or normally open construction. Operating pressure differential 5 to 1250 PSI for AC operation and 5 to 1000 PSI for DC operation.

TWO- AND THREE-WAY HIGH FLOW SOLENOID VALVES—XL SERIES

These diaphragm type solenoid valves meet the high flow requirements of a great many commercial and industrial applications. The unique Skinner diaphragm construction makes possible the exceptionally long service life of this series valves.

Two-way XL series valves are available normally closed and normally open. Orifice sizes are $\frac{1}{2}$", $\frac{3}{4}$" and 1" with corresponding NPTF pipe connections. The $\frac{1}{2}$" orifice model is also available with $\frac{3}{8}$" NPTF. Operating pressure differential is 5 to 150 PSI.

Three-way XL series valves are available normally closed, normally open and directional control. Orifice sizes are $\frac{3}{8}$", $\frac{1}{2}$" and $\frac{3}{4}$" with corresponding NPTF pipe connections. Operating pressure differential is 5 to 150 PSI for the $\frac{1}{2}$" and $\frac{3}{4}$" size and 10 to 150 PSI for the $\frac{3}{8}$" size.

TWO- AND THREE-WAY HIGH PRESSURE HYDRAULIC SOLENOID VALVES—X10 SERIES

These stainless steel, direct acting, slide-type valves are precision engineered to control hydraulic systems at pressures up to 2000 PSI.

These high pressure hydraulic valves have a $\frac{3}{32}$" inlet and cylinder orifices with $\frac{1}{8}$" NPT. They can be used as two-way normally closed or two-way

normally open valves by plugging the appropriate port, and three-way normally closed, or three-way normally open, or dual purpose valves.

• • •

For complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

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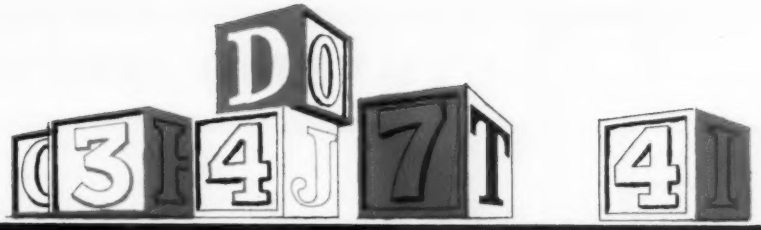
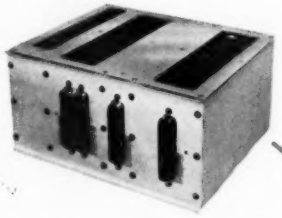


LITTON DIGITAL COMPUTER COMPONENTS



Operational airborne general purpose digital attack navigation computer system. One of many systems through which Litton computer components have been developed.

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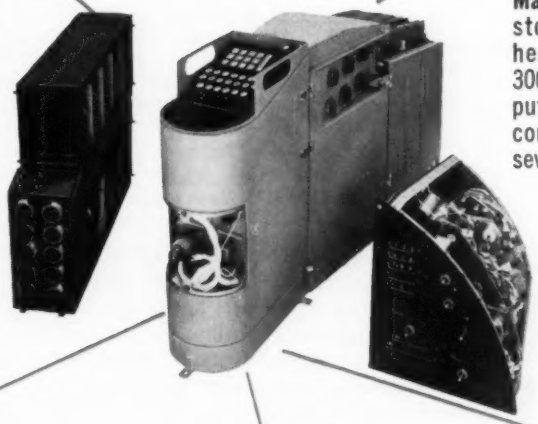
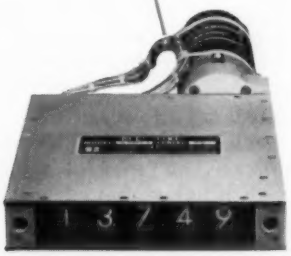


Magnetic Drums. Nickel cobalt storage medium and contact heads. Typical specifications: 300 bits/inch, 500 millivolt outputs, 100 milliampere P.P. recording currents. Suitable for severe environments.

Shaft Encoders. Miniaturized analog-to-digital converters. Extremely small, light, rugged, reliable. Low torque permits weight and volume savings in associated servo components.



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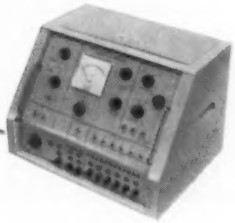

Test & Support Equipment. Clock track and drum fill recorders, shaft encoder tester, tape editor, card tester, servo tester, and Bace.

Direct inquiries to Marketing Department Special Products, Litton Systems, Inc., Guidance and Control Systems Division, 5500 Canoga Avenue, Woodland Hills, California.

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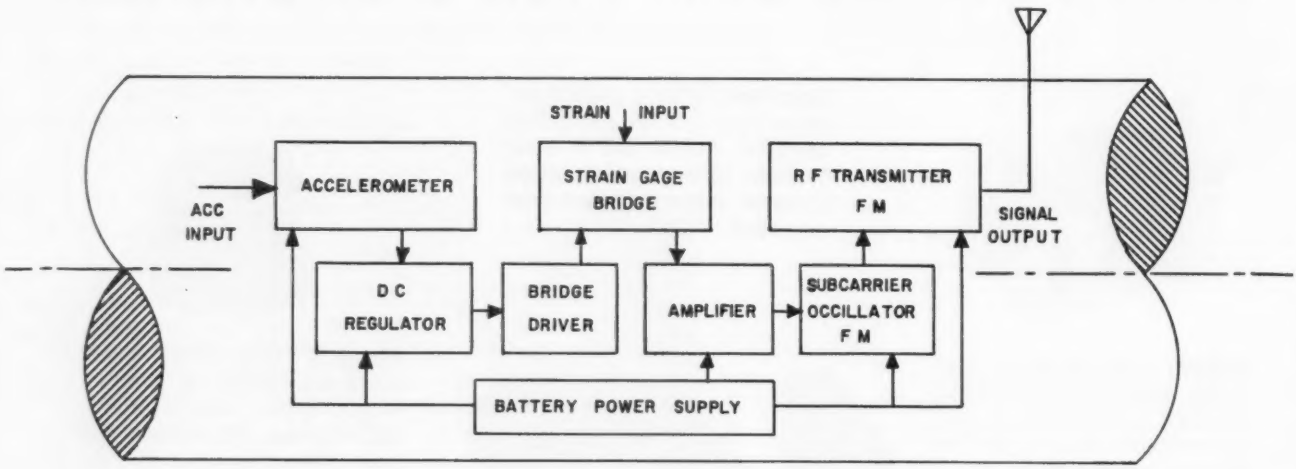
← CIRCLE NO. 13 ON INQUIRY CARD



RADIO TELEMETRY REPLACES SLIP RINGS

Miniature Multichannel FM/FM Systems With High Signal-to-Noise Ratio Transmit Low-Level Test Signals From High Speed Shafts

Taking test data from high speed rotating equipment such as propellers, turbines and driveshafts has presented problems where the data is derived from strain gages, thermocouples or other sensing devices that provide low-level signals. The only method of transmitting the signals from the rotating member to a test stand has been through slip rings which introduce noise levels that tend to obscure the data making it invalid.

To Unilectron Inc., Cambridge, Mass. an obvious solution to these problems was to take full advantage of modern techniques in design and packaging of electronic equipment to develop a radio transmission system so small that it could be located with the sensing elements on the rotating member without disturbing the operation of the equipment. The transmitter is a solid-state multichannel instrument that operates in the FM/FM mode and can handle low level signals with minimum noise interference under extreme environmental conditions. Six separate channels of information are provided in one tiny package with the rugged characteristics of portable field equipment and precision accuracy of a laboratory instrument. Transmitted signals from the channels are picked up by a VHF FM receiver in a test stand where they are discriminated and amplified to drive readout devices.

The system, called Midas which stands for Miniature Data Acquisition System, not only takes accurate data from equipment rotating at high speed, but in many cases it provides the only dependable means of picking off measured information from translating or vibrating equipment such as rocket sleds or vibrating transmission lines. It also provides means for making physiological tests on patients under various conditions of activity.

Use of the FM/FM mode of operation in the system was an obvious solution to the problem of transmitting and receiving low-level multichannel signals with minimum interference between channels. It allows high-gain amplifications in a small package without signal coupling and without using excessive degeneration involving high power dissipation.

Modular design was used throughout the system to make it adaptable to a wide variety of applications and to ensure reliability and serviceability.

Power Meter

One of the more interesting applications of Unilectron's telemetry unit is

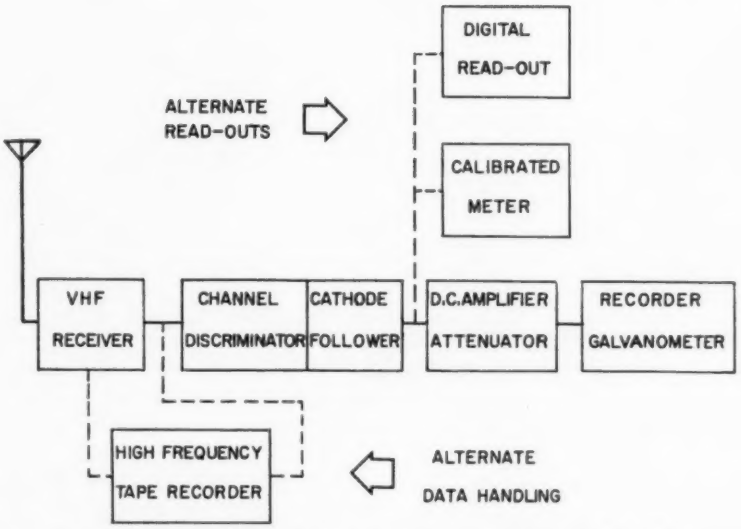


Fig 1 (Left) Completely solid state radio telemetry system called Thor measures horsepower of a high speed shaft and transmits this data to a receiving system where it is continuously indicated or recorded. A strain gage bridge, with all four elements active, is located on the shaft in the classic configuration. When these gage elements are correctly placed and balanced, the signal output is directly proportional to shaft torque, as determined by the formula: Torque (inch-pounds) = G (shearing modulus) x Ip (polar moment) x [2 E (surface stain) / r (shaft radius)]. The signal output can be calibrated directly in terms of torque, provided the voltage driving the bridge is held constant. If this voltage is varied in amplitude as a function of shaft angular velocity, the output signal from the bridge will be proportional to shaft horsepower, as determined by the formula: HP (horsepower) = [Torque (inch-pounds) x N (shaft rotation per minute)]/63000. A potentiometer-type accelerometer mounted with its input axis on a radial line of the shaft is used to vary the bridge supply voltage. The output from the accelerometer is fed through a dc regulator circuit to an oscillator which drives the strain gage bridge. Design of the oscillator is such that a variation in input voltage causes a direct linear change in output signal. In this application, the bridge driving voltage is a sine wave chosen for ease in signal handling. The strain gage signal which is proportional to horsepower is then amplified and transmitted through FM radio telemetry.

Fig 2 (Above) At some remote point, the signal from the Thor radio transmitter is received by a VHF FM receiver, discriminated to obtain the sub-carrier frequency, discriminated again to produce an output signal proportional to frequency deviation, and then amplified and applied to one of several types of read-out devices, as desired, for continuous indication of horsepower.

in "Thor" Meter which measures horsepower, torque and rpm of a rotating member and transmits this data to stationary receiving equipment where it is continuously indicated or recorded.

Conventional dynamometer equipment, such as a Prony brake, are unsuitable for monitoring shaft power continuously because they load the system unduly. Metering techniques are not satisfactory in most applications because of space requirements, inaccessibility or hazardous conditions. A typical example is in the ship building industry where the power developed by a ship's propulsion shaft must be measured. Present methods are hampered by the massive size of the shaft and the need for precise adjustment and constant maintenance.

Thor provides a method for monitoring and continuously recording plant performance without modifying the shaft or effectively increasing its inertia. Horsepower output per unit of fuel consumed accurately establishes overall plant operating efficiency and provides a basis for reducing operating costs.

For a particular Thor application, speed, size and location of the shaft determine the design of the package. A representative installation for measuring horsepower of a merchant marine vessel would fit into less than six square inches of space and weigh less than five pounds. • • •

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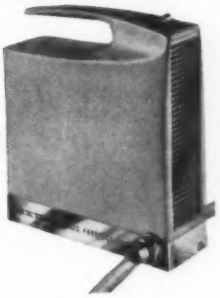
versatile

HEINZE

B

MOTOR

powers portable pump



Here's just one example of the versatility of the Heinze B Universal Motor — operating at 2500 rpm, 1/40 hp, 4V DC, to power this compact portable pump manufactured by the Russell Harrington Cutlery Company, Southbridge, Mass.

Because of its versatility, the B Motor is ideal for such applications as rug cleaners, toy automobiles, electric brooms, vacuum cleaners, and power tools. Horsepower ratings may be supplied from 1/40 to 1/3. Load speed can vary from 2500 to 20,000 rpm. Voltage ratings range from 4V to 220V, AC, DC or AC/DC. Motor is furnished in steel or die cast case.

WRITE FOR COMPLETE INFORMATION.

HEINZE ELECTRIC COMPANY
685 Lawrence St., Lowell, Mass.

SUB-FRACTIONAL HORSEPOWER MOTORS AND BLOWERS

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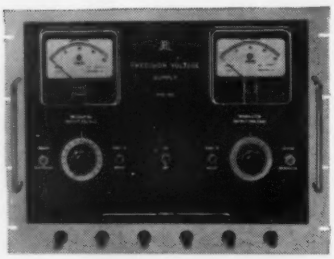
THE LEADER IN ACCURACY



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UNUSUAL INSTRUMENT FEATURES

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The PVS power supply is available in production quantities. Call or write for detailed technical specifications.

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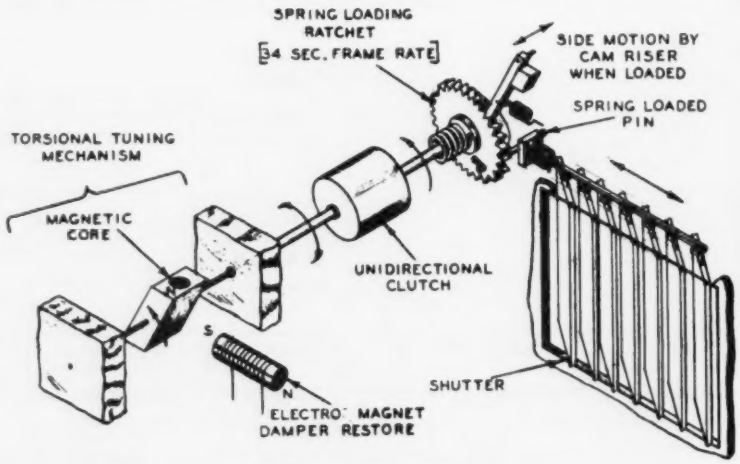
SYSTEMS DESIGN



MECHANICAL SHUTTER ACTUATOR

To get a very accurate exposure interval for a slow frame rate TV system, Dumont Military Electronics, Div. of Fairchild Camera & Instr. Corp., has come up with a unique design that requires very little electrical power and will operate for long periods of time. The shutter, operated by pendulum action, was designed by William J. Long, of Dumont's Product Design Lab.

Unit consists of a torsional tuned mechanism, small electromagnet, unidirectional clutch, spring loading ratchet, and a venetian blind type shutter. The torsional pendulum can be set into motion by a preload which can be released and synchronized with the frame rate pulse. Once in motion, it will oscillate at its natural frequency. Any lost amplitude per cycle is restored by the magnet. The electromagnetic field is energized only at the moment when the energy lost by the torsional pendulum is to be restored. During every cycle a portion of the total spring loading is applied to the ratchet mechanism. When it is completely loaded, the pawl is released and the shutter is opened. The natural frequency and the amplitude of the pendulum directly relates to frame rate and total force necessary to activate the shutter.

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WORTH FILING

Electromechanical Parts

552-page inclusive catalog divided into sixty-seven product categories, includes speed reducers, magnetic clutches and brakes, differentials, electronic hardware, teflon terminals and limit stops. Within each category, part numbers, OEM list prices, specifications and test reports useful in design and prototype work are presented.

Source: Sterling Instrument Div.
Designatronics, Inc.
Port Washington, N. Y.

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Test Instruments

220-page catalog contains descriptions of more than 400 test instruments. Application data includes latest measuring techniques. Equipment covered: oscilloscopes; oscillators; power supplies; generators; wave and distortion analyzers; ac and dc voltmeters, ammeters and ohmmeters; amplifiers; frequency and time measurement equipment and other instruments. Microwave section is divided into power, impedance, and noise figure measurements, and other microwave equipment.

For your copy write on company letterhead to:
Hewlett-Packard Co.,
1501 Page Mill Rd.
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Self-aligning Bearings

56-page catalog describes entire line of self-aligning bearings and rod end bearings. Included is new series of plastic alloy insert, self-lubricated bearings which are available in a variety of plain or rod end types. Bore sizes are available up to 6.000″; ultimate static loads up to 4,500,000 lbs.

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7 TYPES OF LOAD CIRCUIT OPERATION ALL IN A SINGLE UNIT

Bristol's new Series 6100 gives you easy application with exclusive flexibility. No more complex wiring changes! Make circuit changes in a jiffy, too. You can reach the motor, and other parts—in seconds. The new "Bristol-Vision" dial is mounted in a square die-cast frame—provides better contrast for better viewing plus functional beauty too. Non-scratch bevelled *glass* dial cover won't buckle, deform—seals against dust. Powered by famous duty-matched standard Bristol motor. Write for brochure.

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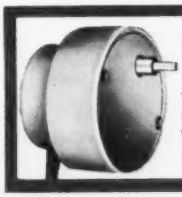
SEND FOR HANDY TIMING CONTROL PRODUCT DIGEST —complete range of Bristol Motors, Timers and Timing Devices for all your timing and control applications.



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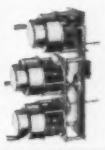


BRISTOL (B) MOTORS *Division of Vocaline Company of America, Inc. / Old Saybrook, Conn.*

CIRCLE NO. 17 ON INQUIRY CARD

HIGH DENSITY WELDED PACKAGES

By S. Liss and V. Maida,
Kearfott Division, General Precision, Inc.

Welded Cordwood Packaging Techniques as Used in Polaris Digital Computer Extended to Analog Systems Applications

Recognizing the increasing need for higher packaging densities together with greater reliability in electronic equipment for high-performances systems, Kearfott engineers realized some time ago that standard packaging techniques would soon be inadequate to meet performance and size requirements, and that industry could not wait upon practical development of such glamorous techniques as molecular circuitry. They therefore instituted an R & D packaging program based on a thorough survey of work in the field, to find the most practical techniques to meet immediate and foreseeable needs.

Although a number of new, miniaturized components, such as the microton capacitor, have been developed, it was decided that the necessity of soldering together the various substrates, as well as the requirement of using components with precise standard configuration, were too limiting for today's requirements of ready availability of acceptable components.

In the use of standard components, random assembly can achieve the highest density. However, the volumetric benefit of this approach was felt to be more than offset by the difficulty in designing such a package, and by the potential confusion (and cost) in assembling a random-placement electronic assembly.

The most practical approach appeared to be the welded, high density, log piling assembly of standard components. This was based on the following criteria:

High volumetric effectiveness (30 - 150 parts per cubic inch)
Design simplicity for new assemblies
Use of a wide variety of available components from many suppliers
Minimum assembly training time
Low design cost
Low fabrication cost for small lot production
Simplicity in tooling for high quantity production
Versatility in interconnection
Size versatility
Interchangeable assemblies

MIT's welded electronic assembly technique, which was used on the Polaris computer so successfully, provided useful background information since it satisfied the established criteria more completely than others. Considerable effort was supplied to translate the technique into a useful production tool for Kearfott applications. The result was a photographic design technique that reduces design time by fifty to seventy-five percent, while at the same time expediting the production process.

The R and D program was organized into five basic areas of study: component analysis, high density packaging, joining techniques, encapsulation, and interwiring. The following paragraphs summarize some of the information and techniques derived from work in each of these areas.

COMPONENT ANALYSIS

When choosing components for military equipment, great care must be exercised to insure that components used in electronic assemblies can withstand the rigors of electrical performance test, as well as environmental exposure, while still performing satisfactorily. For example, carbon resistors can be found to be within the manufacturer's specification during static tests but, due to microphonic action of the carbon/wire connection set up during vibration or shock, these same resistors can go out of tolerance.

What is the smallest (physical size) component that can be used that will do a satisfactory job? In many cases where one-half-watt resistors had been used, investigation into maximum dissipation indicated that one-tenth watt resistors were adequate. The electrical engineers were asked to use the average dissipation characteristics with a reasonable safety factor, taking into account the operating time, load factor, and effect on the circuit. Only when use of average dissipation could under any circumstance allow performance of the overall circuit to go out of tolerance should maximum dissipation be used as a design factor. This eliminated the usual tendency to pile safety factor upon safety factor. The reasoning behind this is the fact that resistors return to original characteristics under standard conditions if they have not been catastrophically destroyed.

Similarly, analysis of capacitors was made to determine minimum safe working voltage units so that minimum volume capacitors could be used. Capacitors were also challenged for their hygroscopic characteristics which would adversely affect both insulation resistance and voltage breakdown characteristics.

In both of the above cases, uncased components were used freely since it was understood that ultimately the assemblies would be potted, which would provide sufficient insulation, shock protection, and moisture resistance. This, however, is not true for transistors and diodes where it is necessary to insure hermetic seals to preserve component characteristics.

Transistors were chosen first for electrical characteristics, second for package size, and third for thermal characteristics when necessary. However, this order caused a problem when dealing with the output stages of servo amplifiers where five watts or more had to be dissipated. In this case, we decided to accept operation under the nominal 70°C, 100°C, or 125°C required-ambient conditions, which then dictated the choice (and price) of components. However, the electronic assemblies can likely be used in higher temperature environments provided the high density electronic assemblies are mounted on a cold plate of a material (such as honeycomb manufactured by Air Research Division of Garrett Mfg.) through which a cold gas or liquid can be passed for heat dissipation.

It is helpful to request component manufacturers to use Nickel or Dumet lead wire in order to simplify weld settings for later fabrication.

Components such as potentiometers, synchros, resolvers, motors, optical pickoffs, etc., which in themselves are functioning assemblies, are subject to dynamic errors which can exceed static measurements. These errors can be due to: assembly inaccuracies; mechanical instability; dynamic failure of bearings, and brush and slip ring assemblies; character and quality of insulation material; and natural frequency of the entire device as a minor vibrating system. The important thing to remember here is that these aberrations are more pronounced in high density packaging.

HIGH DENSITY PACKAGING

High density packaging involves laying out components in an electronic assembly into a minimum volume. Some arbitrary definitions were established by Kearfott to facilitate study of this area.

Weldbloc: the smallest completely functional group of components assembled and connected in a standardized modular package.

Weldstac: a group of Weldblocs interconnected into a small assembly to perform a minor system function.

Some design criteria considered were:

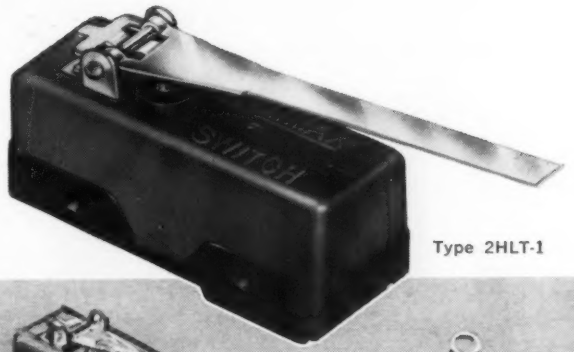
- What is the largest component? Let this or multiples of this size establish one or more guiding dimensions.
- Can log-piling help? Log piling (also called the "cordwood technique") is the placing of cylindrical components side by side, with leads parallel. An additional space saving technique is placing the body of a component adjacent to lead wire of the one closest to it. In this case, it is necessary that there by a minimum of 0.10 inch clearance in order to leave room for the welder electrode tips during fabrication. Log piling was chosen as the best compromise since it provided reasonable space savings as well as a simple, logical layout technique, even though a random component assembly program would have resulted in higher density.
- Minimize the number of levels of component wire connection by eliminating wire crossing wherever possible.
- Heat dissipating devices may be placed in close proximity to the built-in heat sink which then is designed for mounting to the external thermal dissipator.

Whenever possible, maximum number of components should be mounted on the periphery of the assembly so that simple replacement before potting can be achieved. In one approach, called the peripheral method, the components are assembled into units in the form of circular wafers, squares, rectangles, or long sticks of substantially rectangular cross section. These units can then be stacked or placed side by side and thereafter simply interconnected. Subassembly is accomplished by welding the component leads to strip wires or to other component leads to form a rugged assembly prior to potting. Simplicity in repair and maintenance is thus achieved.

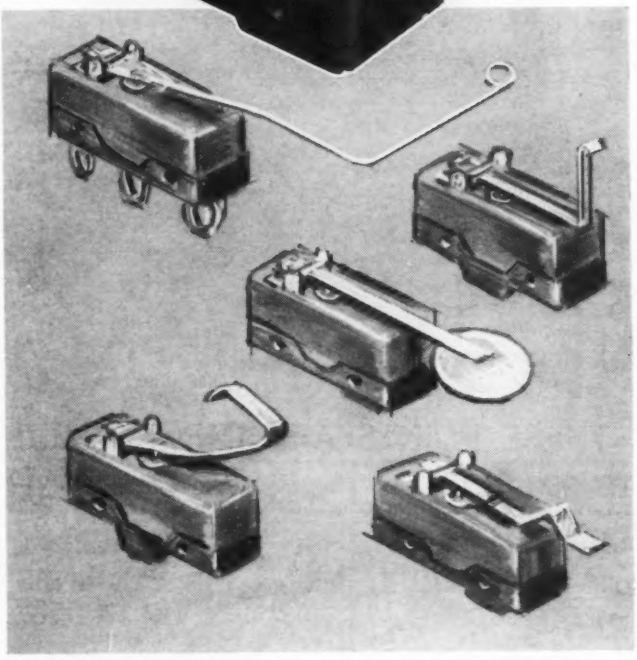
UNIMAX

LEVER-ACTUATED

SWITCHES



Type 2HLT-1



Cut manufacturing costs by eliminating complex linkages and mechanical couplings. Levers, in hundreds of special shapes, suit individual needs.

The standard Type 2HLT-1 switch shown is 1 15/16 x 11/16 x 1 5/64 inches with a 2 1/2-inch rigid-lever actuator. Some special levers we have furnished are shown; we'll design to fit *your* requirements.

Basic UL rating of Unimax 2HL series is: 1 hp 125 v. a-c; 2 hp 250 v. a-c; 20 amp. 125, 250, 480 v. a-c; 10 amp. 125 v. a-c lamp load. Write for Catalog 123, containing basic data on the entire Unimax Switch line.

Local distributors now stock Unimax switches for your convenience.

UNIMAX SWITCH

Division Marion Electronics Corporation

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BREAKTHROUGH IN PRESSURE SWITCH ACCURACY

at reduced prices

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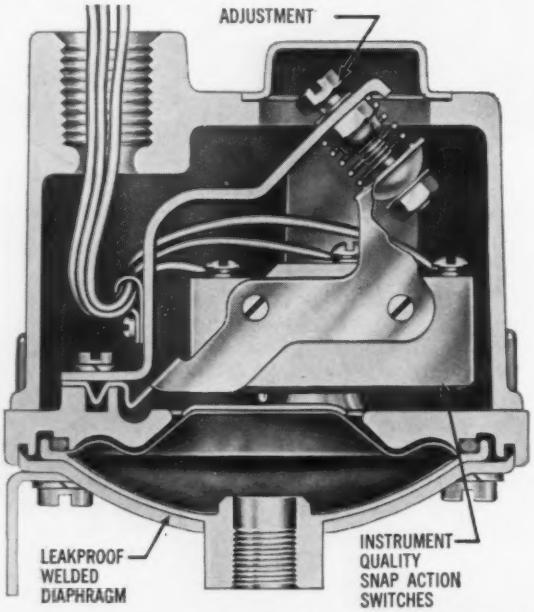

THESE POINTS ARE IMPORTANT

WE BUILD IN	WE DON'T USE
EXTREME ACCURACY and DEPENDABILITY maintained during operating life due to direct acting design	LINKAGES & BEARINGS which, as they wear, make the setting of the pressure switch drift.
OPERATION IN ANY POSITION which saves the installation costs encountered in mounting a switch that uses liquid switching elements	LIQUID SWITCHING ELEMENTS which make the switch difficult to mount and very critical to vibration.
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Another method which was considered, the master film method, is the use of two films with all components sandwiched between them. These films contain the wiring diagram, the placement and nomenclature of components, electrical outputs and inputs, and electrical information for checking the completed package.

Of the two methods described above, the latter was chosen and developed into a working procedure because it afforded the most straightforward method of assembly, and seemed most amenable to being developed into a production technique. Additional benefits which accrued were minimization of assembly errors due to component transposition and omission, and to poor wiring and spacing.

This method was built around the use of ten-times-size component templates, and a transparent base master. These templates are arranged within two standard outside dimensions set up for the assembly. (The third dimension is controlled by number and size of components.) The procedure is as follows:

The designer places the marked component templates on a clear layout film. The templates must be oriented to achieve the shortest possible wire route from one component to another.

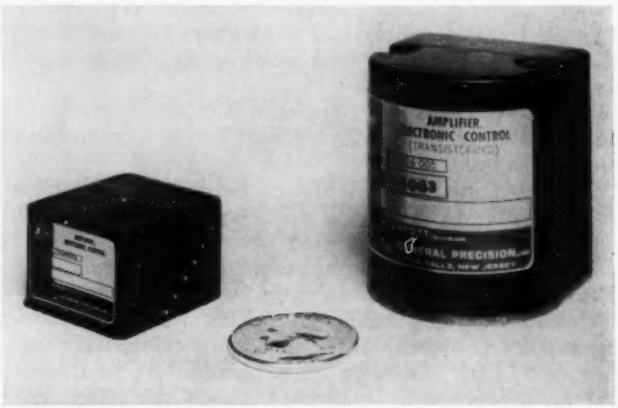

Fig 1 Miniaturized five-watt servo amplifier (left), a result of Kearfott's packaging program, is 1/5 the volume and 1/4 the weight of its predecessor.

Consideration must be given to just how output leads are to be terminated on each package. If output leads are to terminate on a side of the package, no less than 3/32" can be allotted to accommodate the leads and output pins. (See Fig 1.)

When the template layout is completed, it is analyzed with respect to size and configuration. If satisfactory, the layout is sent to the photo lab for a contact negative. This negative is now used to obtain a face-up print for the top and a face-down one for the bottom. If the layout of the top and bottom indicate no crossing of wires and that all points can be connected and welded without difficulty, the 10 to 1 negative is sent back to the lab for a contact positive. A face-up contact positive is shown in Fig 2.

Tape is used to wire from point to point, joining all the components such that no cross wires will exist. In this way, single layers of wiring on top and bottom (see Figs 3a and 3b) of the subject assembly can be achieved.

If it is possible to have all the wires connected without crossing, the assembly procedure can proceed; but if the

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Input Impedance, ohms	50,000
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Operating Temperature Range in °C	minus 50° to plus 50°

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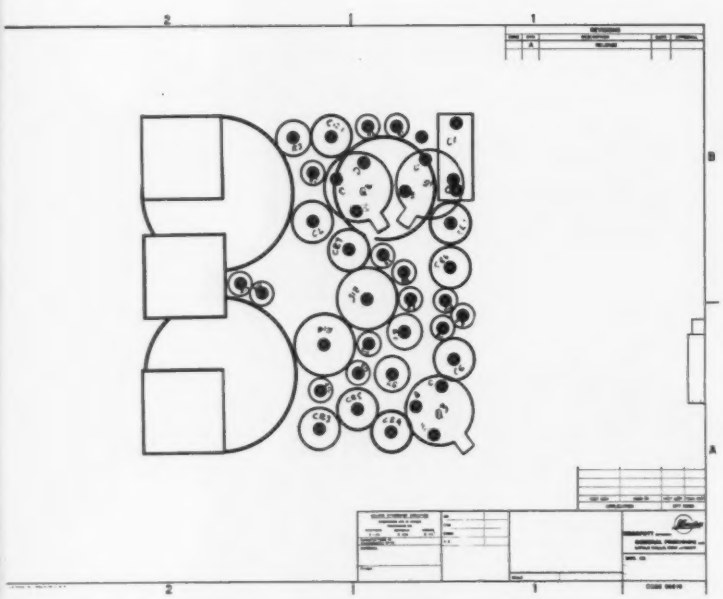

Fig 2 First step in the packaging procedure: ten-times-size component templates are laid out on clear film and oriented to achieve shortest possible wire route from one component to another.

wires cross one another, then separators must be planned, creating a second layer of wiring.

The master film layout should also contain all mechanical dimensions such as length, width, height, scale and a controlling dimension for reduction purposes. Location of this dimension is indicated in Fig 3. The targets at either end of the controlling dimension are used after final reductions to accommodate the package spacers which will fix the film spacing (package height) during the welding operation.

The master layout is now completed and represents a document indicating the point to point wiring (path to be taken by the nickel ribbon) for the top and bottom of the proposed welded package.

The completed master layout is now ready for final reduction. The reduction from a 10 x 1 master to the final size as indicated by the target dimension is accomplished on Eastman-Kodak Mylar or DuPont Cronar material. An intermediate two-times-size print can be used by the model or production shop as a production aid.

JOINT TECHNIQUES

The following joining techniques were considered: Soldering techniques, both individual point and dip soldering, were considered and were eliminated because, due to flux residue degradation, it is not possible to predict length of function life. Further, quality control of individual solder joints is difficult to maintain in production.

Epoxy joining methods were rejected for it was felt that more experimentation was required to confirm their usefulness.

Resistance welding, however, permits metallographic

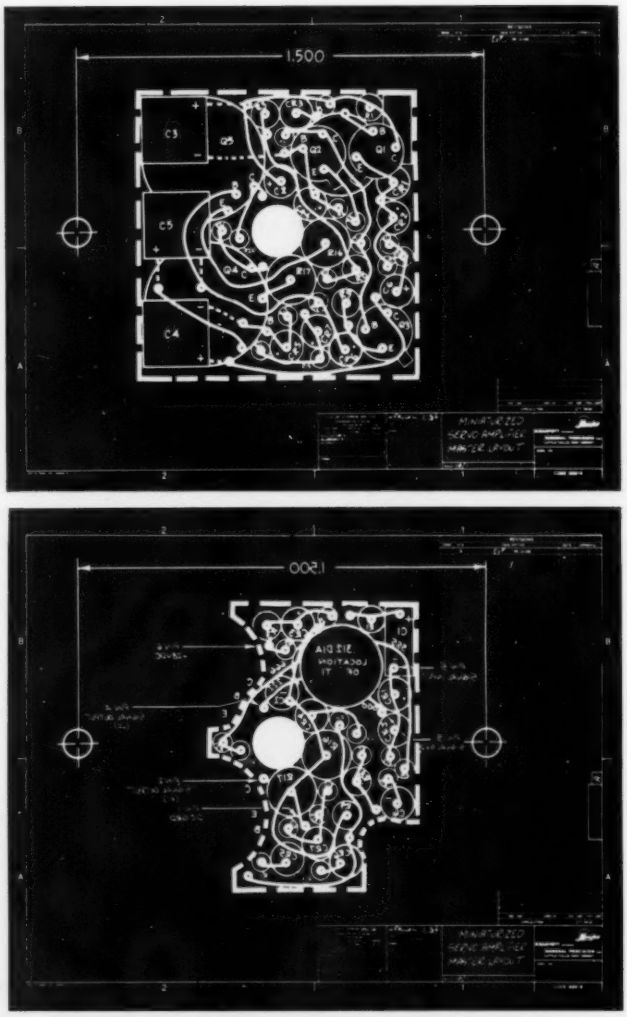

Fig 3 The template layout shown in Fig 2 is photographed from top and bottom to obtain a face-up print for the top and a face-down one for the bottom.

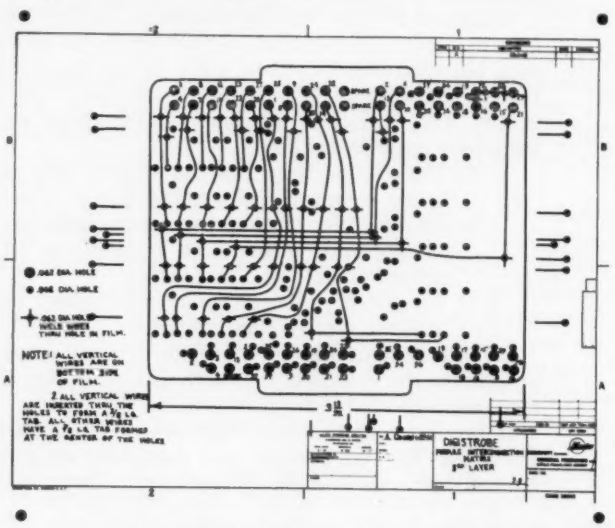

Fig 4 One of four films used in Point-to-Point Multilayer Mother Board for interconnecting individual Weldblocs in Kearfott's Digistrobe Display Device. Weldbloc connections feed through and are welded to grommets (circles) in the Mother Board.

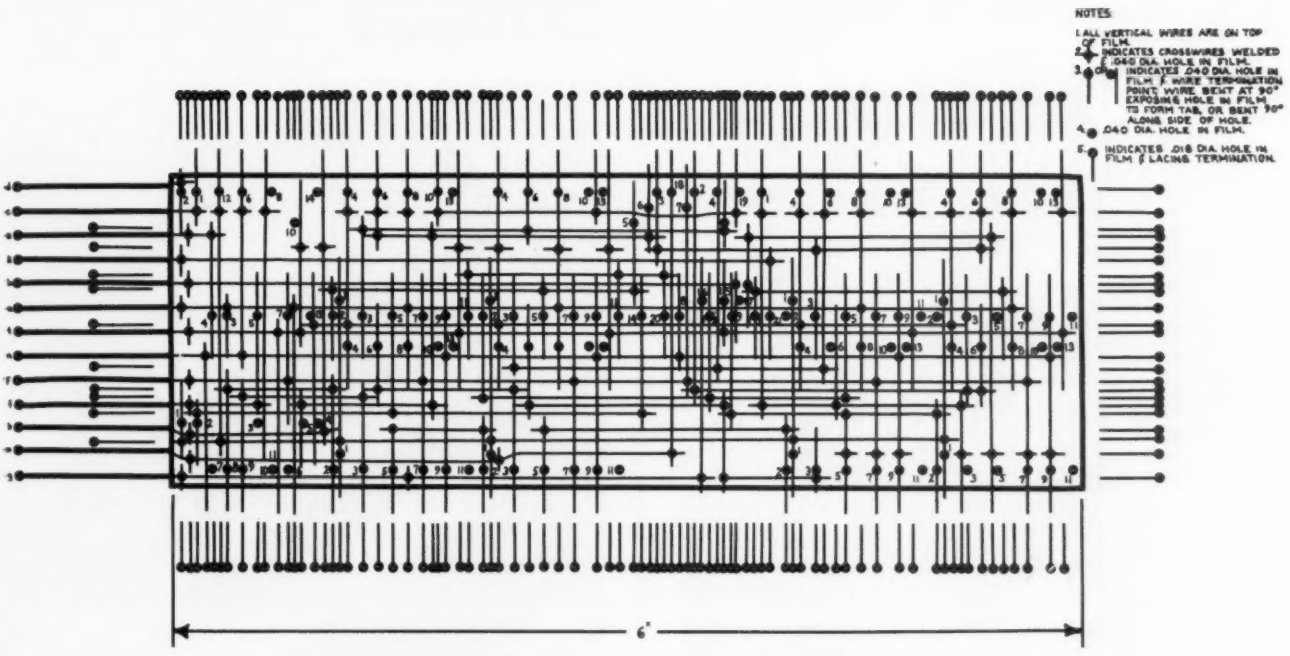
NOTES
1. ALL VERTICAL WIRES ARE ON TOP OF FILM.
2. INDICATES CROSSWIRES WELDED
.040 DIA. HOLE IN FILM.
3. INDICATES .040 DIA. HOLE IN FILM. F. WIRE TERMINATION POINT, WIRE BENT AT 90° EXPOSING HOLE IN FILM. TO FORM TAB, OR BENT 90° ALONG SIDE OF HOLE.
4. .040 DIA. HOLE IN FILM.
5. INDICATES .018 DIA. HOLE IN FILM & LACING TERMINATION.
6"

Fig 5 Straight Line Grid Mother Board is similar to Point-to-Point type except that all interconnection wiring is made via strip wires placed perpendicular to each other, with welded junctions for continuity.

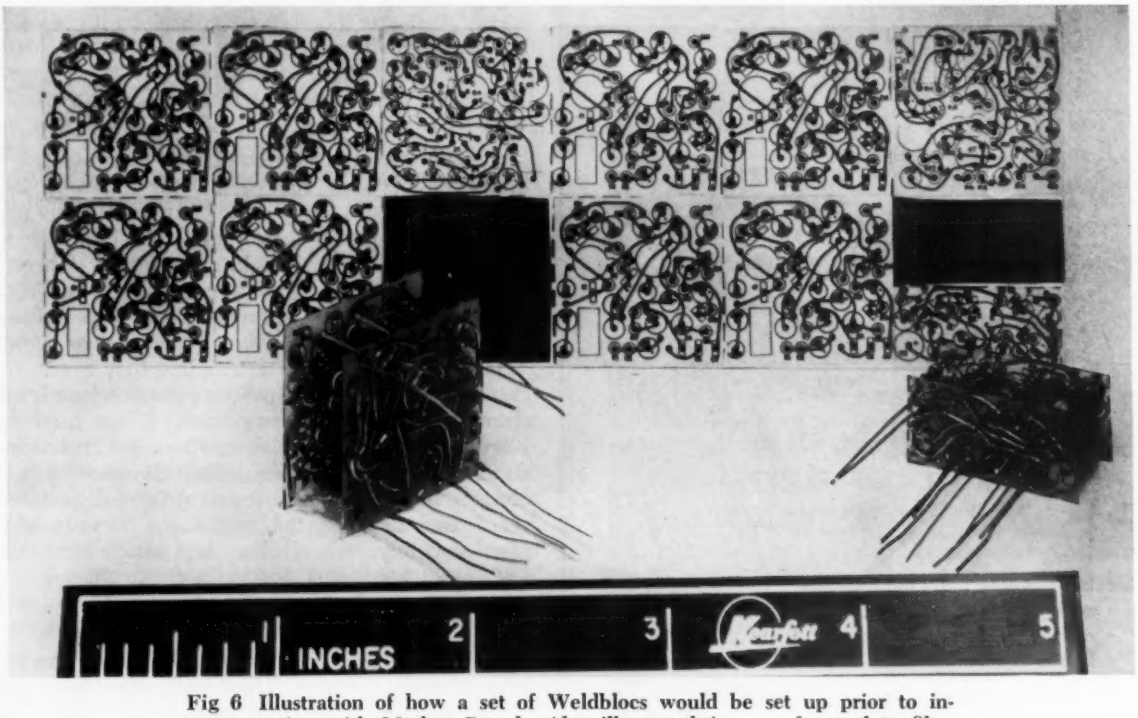

Fig 6 Illustration of how a set of Weldblocs would be set up prior to interconnection with Mother Board. Also illustrated is use of template film.

verification, which is the basis of a predictable level of quality, essentially beyond the control of the operator. By adjusting the contact pressure and electrical energy flow, and by experimentation with particular connection materials of known cross section, junctions can be made with consistent pull strength (tensile force necessary to rupture a connection). The result is a package which has no weaknesses in any direction.

Since welding is a process based upon the principle that a high current flowing through two pieces of metal between electrodes will heat the pieces to their fluid state for actual alloying, there is no need for a flux for wetting, oxide removal, or other surface preparation. Thus, no cleaning is necessary after component connection.

Further welding techniques, detail schedules, and philosophy are discussed in welder manufacturers' literature.

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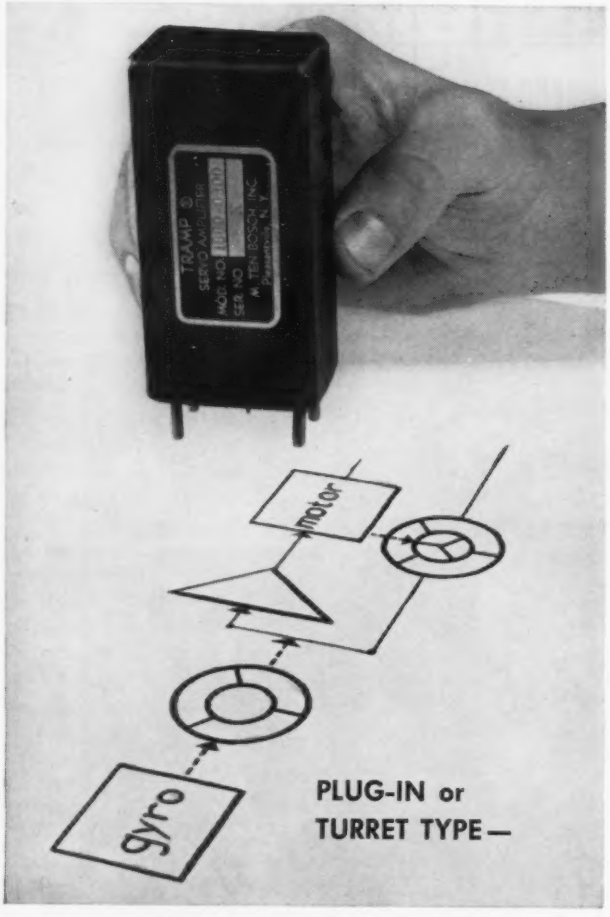

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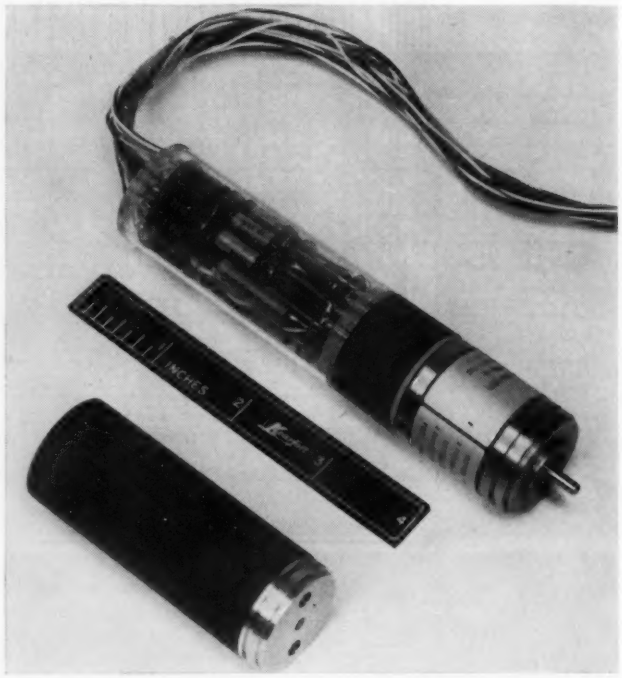

Fig 7 Resolver buffer amplifier rides "piggyback" on its resolver, eliminates interconnection cables with associated noise and pickup problems.

ENCAPSULATION

Some important considerations in encapsulation are: The difference between the coefficients of expansion of the component lead wires and the component body materials is sufficient to rupture their junction if both are locked in vise-like pressures of a rigid encapsulant. Therefore, it is necessary to provide some type of silastic coating over the components prior to potting so that the rigidity of the encapsulant will not shatter the components within.

In the small volume assemblies that result from high density packaging, encapsulants must be analyzed for resistance to hygroscopic exposure. When used on assemblies such as buffer amplifiers where R/C trimming and resistance ratio balance are important, encapsulants can cause changes in the insulation resistance and distributed capacitance, thus affecting the operational linearity of the complete assembly.

INTERWIRING

Interwiring of the individual Weldblocs can be accomplished in several ways. Three techniques were considered:

The Point-to-Point Multilayer Mother Board technique was used in the Kearfott Digistrobe Display Device. One of the four films used in this multilayer mother board is shown in Figure 4. The Weldbloc connections feed through and are welded to grommets in the mother board. These are then interconnected via nickel strip wire laid out along the paths printed on the mother board.

Molded separators maintain parallel spacing between adjacent nickel strip wires in the same plane. By using the same material for the separators and encapsulation medium, the separators can actually dissolve into the encapsulant. By this method, the separators serve their purpose of maintaining alignment of the interwiring strip wire until the encapsulant takes hold.

If the film material were made from a compatible plastic, it, too, would dissolve leaving only the photo sensitized emulsion, depicting the wire runs in the individual levels. Thus the stratification due to film separation is eliminated.

Straight Line Grid Mother Board, shown in Figure 5, is similar to the Point-to-Point type except that all interconnection wiring is made via strip wires placed perpendicular to each other, with welded junctions for circuit continuity. Experience has shown that this technique, though simpler for the welder and simpler to automate, takes additional volume and sometimes more interconnection strata than Point-to-Point boards. Figure 6 shows how a set of Weldblocs would be set up prior to connection with a Mother Board.

Connectors can also be welded or soldered to individual Weldblocs to fabricate plug-in assemblies (see Figure 7). However, use of connectors will reduce savings in volume obtained by high density packaging and will also reduce potential reliability by whatever unreliability is inherent in the connector.

After Weldblocs are joined via mother board into a Weldstac, the latter can then be connected with flexible cable to other Weldstacs. These cables can be welded to each other, and finally terminated in one connector from the electronic system.

RESULTS

Effectiveness of Kearfotts new packaging techniques are illustrated in two examples.

A production servo amplifier, shown in Fig 1, is 1/5 the previous volume and ¼ the weight of its predecessor, at no increase in cost.

A resolver buffer amplifier rides "piggyback", (see Fig 7) eliminating interconnection cables with concomitant noise and pickup problems.

Designs of standard electronics for inertial equipment have provided reduction of four to one in volume and two to one in weight, with improvement in reliability. • • •

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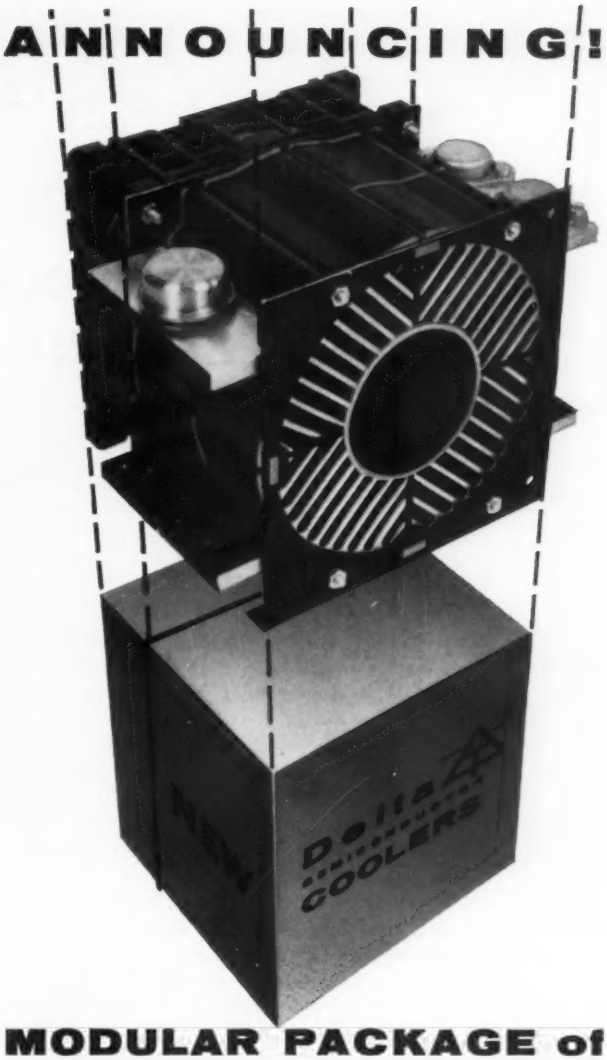

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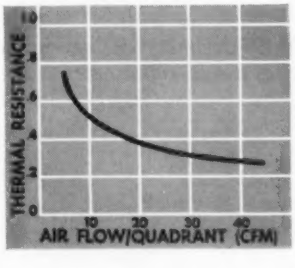

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PELTIER COOLING OF HOTSPOTS

Many reports that have come to our attention foresee in the immediate future the practical application of the Peltier effect to hotspot cooling. However, a study made by Donald S. Gage, Asst. Prof. of Electrical Engineering at Northwestern University, suggests that much more work will have to be done before Peltier cooling of hotspots is practical. In a paper presented at the 16th Annual National Electronics Conference, Gage compared the effectiveness of reported thermoelectric materials to ordinary heat conductors in removing heat from hotspots in compact equipment.

In conventional refrigeration, Gage explained, the thermoelectric properties of the materials are used to move heat "uphill," that is, from a lower to a higher temperature. The larger the temperature difference, the more important it is that the materials have a low heat conductivity. When cooling hotspots, however, the thermoelectric properties of the materials merely aid the flow of heat in the natural direction – "downhill." The larger the temperature difference, the more desirable it is for the materials to have a high heat conductivity.

Theory has shown that the figure-of-merit for material used in refrigeration cooling is $a^2/\rho\kappa$. However for hotspot cooling, Gage found a figure-of-merit of a^2/ρ. Therefore, he concludes, it is necessary to examine combinations of metals all over again; for materials not suitable for thermoelectric cooling in the refrigeration sense might be very suitable for cooling in the hotspot sense.

Principal difference between the cooling of hotspots and conventional refrigeration, seen in the two figures-of-merit, is the role of the thermal conductivity κ. According to Gage, much effort is directed towards decreasing this heat conductivity, since the present search for thermoelectric materials is guided by the $a^2/\rho\kappa$ figure-of-merit. Should some of this search be guided by the a^2/ρ figure-of-merit, he contended, the effort could be reoriented to decreasing the electrical resistivity ρ. In general, he stated, the thermoelectric power a can not be changed significantly by doping, changes in the crystal structure, etc. The following section shows how Gage derived the figure-of-merit for hotspot cooling and how he applied it to a specific problem to demonstrate that heat conduction in ordinary copper is superior to the use of reported thermoelectric materials.

COOLING OF HOTSPOTS

Basic equation describing the rate at which heat can be absorbed in the vicinity of one junction (the hotspot) is:

$$Q_{SRC} = aT_1I + K(T_1 - T_0) - (1/2)rI^2 \quad watts \qquad (1)$$

where
$$a = |a_1 - a_2| \quad volts/°Kelvin$$
$$K = K_1 + K_2 = \kappa_1 S_1/l_1 + \kappa_2 S_2/l_2 = watts/°Kelvin$$
$$r = r_1 + r_2 = l_1 \rho_1/S_1 + l_2 \rho_2/S_2$$

Equation (1) consists of three terms which collectively determine the rate at which heat is removed from the left junction in Fig 1 (b). The first term is the rate of heat removed from the junction at temperature T_1 by Peltier cooling. The second term is due to ordinary heat conduction. The last term is the rate at which Joule heat is supplied to the junction and assumes that the wires are perfectly insulated and therefore can lose none of their Joule heat to the surroundings by any means of heat transfer other than lateral transfer to a junction. The division of Joule heat between the two junctions becomes apparent if one considers the situation in which $T_1 = T_0$. Under this hypothetical condition, assuming a uniform geometry for both wires and neglecting the Peltier effect, the center of each wire will be heated somewhat, and one half of the Joule heat will flow to each junction. Under an actual condition of a hot and cold junction, the change in heat flow to each junction is equal to the second term in equation (1), consequently, the superposition of the second and third terms gives the rate at which heat is

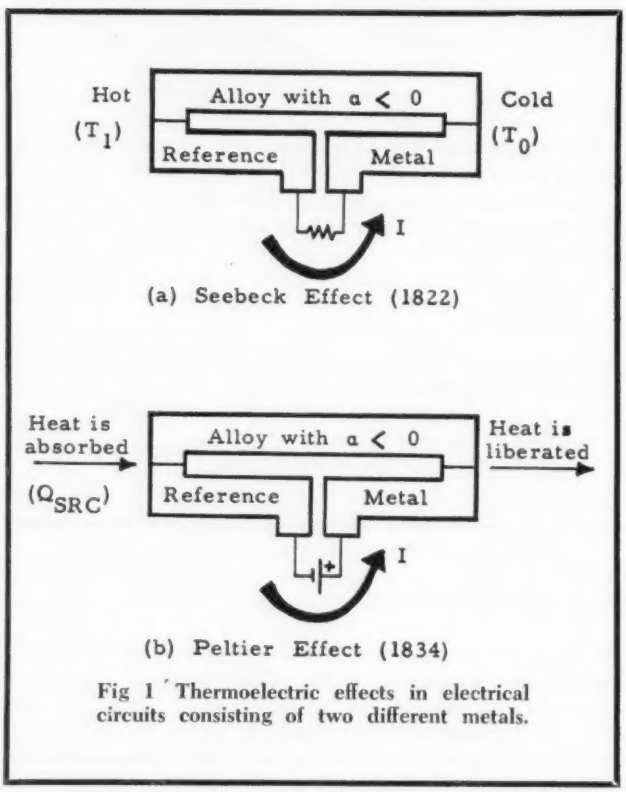

Fig 1 Thermoelectric effects in electrical circuits consisting of two different metals.

removed/supplied under the assumed conditions. The actual rate of heat removal from the source – Q_{SRC} – is given by the linear superposition of the terms which represent the Peltier effect, ordinary heat conduction, and the I^2r heating in the wires.

Since the objective is to remove heat from a hotspot, it is logical to seek a maximum for Q_{SRC}. Q_{SRC} can be increased by increasing the temperature difference and maximized by using the optimum value of current.

$$dQ_{SRC}/dI = a\,T_1 - rI = 0 \qquad (2)$$

$$I = a\,T_1/r \quad amps \qquad (3)$$

Equation (3) is the current at which the rate of heat removal is a maximum. Therefore,

$$Q_{SRC}\ (max) = (1/2)\ T_1^2(a^2/r) + K\ (T_1 - T_0) \qquad (4)$$

If $l_1 = l_2 = l$, $S_1 = S_2 = S$, and $\rho = \rho_1 + \rho_2$,

equation (4) becomes:

$$Q_{SRC}\ (max) = (1/2)\ T_1^2 F_h\ (S/l) + K\ (T_1 - T_0) \qquad (5)$$

where $F_h = a^2/\rho$

F_h is the figure-of-merit for materials used in this application of hotspot cooling.

Gage calculated this figure-of-merit for many combinations of thermoelectric materials and found cobalt-copper and nickel to have the highest. To show the maximum rate of heat removal using this combination, Gage chose the following example.

Suppose the problem is to cool the compact electronic equipment in a satellite. The hotspot is located 50 cm from the surface and the allowable wire size is No. 6 AWG. If $T_0 = T_1 = 350°$ *Kelvin*, equation (5), using the cobalt-copper-nickel figure-of-merit, gives:

$$\begin{aligned} Q_{SRC}\ (max) &= (1/2)\ T_1^2 F_h\ (S/l) \qquad (7)\\ &= 1/2\ (350)^2\ (182 \times 10^{-4})\ (0.133/50)\\ &= 0.0296 \end{aligned}$$

Neglecting heat conductivity, this is the rate at which heat can be removed by these two wires.

Gage then compared the heat removal in equation (7) to the heat that can be removed, through ordinary heat conduction, by two copper wires of the same area S and length l.

$$\begin{aligned} Q_h &= K\ (T_1 - T_0) \qquad (8)\\ &= (2\kappa_{cu})\ (S/l)\ (T_1 - T_0)\\ &= 0.0204\ (T_1 - T_0) \end{aligned}$$

To achieve the rate of heat removal in equation (7), the necessary temperature difference is:

$$(T_1 - T_0) = 1.45° \text{ Kelvin} \qquad (9)$$

This small temperature difference indicates, Gage concluded, that hotspot cooling using reported thermoelectric materials is inferior to heat conduction in ordinary copper. Since the same geometry factor (S/l) appears in equations (7) and (8), a change in wire size or distance will not affect the result.

Summarizing, Gage said, "The best pair of alloys discovered to date can only remove heat from a hotspot at the same rate as provided by heat conduction in pure copper with a temperature difference of 1.5° Kelvin. Metal alloys may exist which have a higher thermoelectric power and a lower electrical resistivity than those now reported. If so, the Peltier cooling of hotspots may become practical." • • •

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Frequency	60 cycles	60 cycles
Stall Power/Phase	6.0 watts	6.0 watts
Stall Current/Phase	70 MA	70 MA
Time Constant	.0052 Sec.	.00915 Sec.
Reversing Time	.0089 Sec.	.0155 Sec.
Rotor Inertia	4.0 gm cm²	3.3 gm cm²
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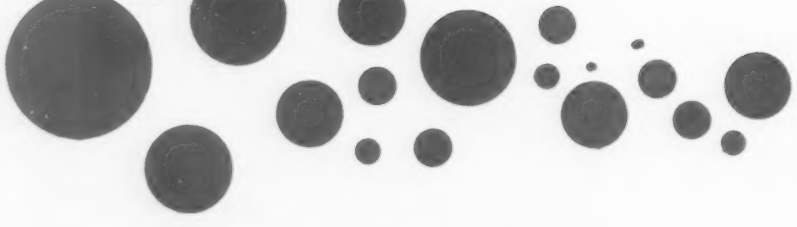


Kermit T. Simons, Senior Engineer
Ampex Instrumentation Products Company, Redwood City, California

INSTRUMENT BALL BEARING SELECTION

Selection of the proper ball bearing for an application can be made only after a thorough study of the static and dynamic conditions of the application, and the environment in which the bearing is to operate. Precision ball bearings have many basic characteristics that are affected by the application, and various factors must be considered in order to take full advantage of the reliability built into ball bearings and determine their expected service life.

LOAD TO BE CARRIED

Instrument ball bearings are manufactured in sizes ranging from 0.100 inches up to 20 inches in diameter. Each bearing has a definite load carrying ability for both static and dynamic loads. The total load that can be carried radially, axially, or as a combination of the two, can be computed. The load-carrying ability is a major criterion when establishing the life expectancy of a given bearing in a given application.

The "Basic Dynamic Load Rating," usually referred to as the "C" factor, is the typical radial load that a group of apparently identical bearings can endure for a rated life of one million revolutions with a stationary load and a rotating inner ring.

The "C" factor may be determined by

$$C = f_c\,(i \cos \alpha)^{0.7}\, Z^{2/3}\, D_a^{1.8}\ lb.$$

where i = No. of rows of balls per bearing

α = Angle of contact
Z = No. of balls per row
D = Diameter of ball, in inches (If $D_a > 1''$, the exponent should be changed to 1.4)
f_c = Material factor, or dynamic capacity coefficient

The material factor, f_c, is proportional to the diameter of the ball and the cosine of the angle of contact and is inversely proportional to the pitch diameter, D_m, of the ball set.

It is seldom necessary for the design engineer to calculate the basic dynamic load rating, or "C" factor, since the manufacturer usually provides him with this information.

Using the "C" factor, the life expectancy for a given bearing can be determined by using the following formula:

$$L_n = (C/P)^p$$

where L_n is the normal life in millions of revolutions; C is the basic dynamic load rating in pounds; p is the radial load in pounds.

However, the load is seldom purely radial. It almost always has an axial load component. Therefore, it is necessary to calculate the combined axial and radial loads, known as the "Equivalent Load." This value, P_r, can be determined by the larger of the two values calculated from the following

(a) $$P_r = VF_r$$

or

(b) $$P_n = XVF_rVF_a$$

where V = the rotation factor
X = the radial factor
Y = the thrust, or axial, factor
F_r = the radial load
F_a = the thrust, or axial, load

$F_a/V\ F_r$ (or the factor e) represents the ratio for which the two equations are equal. (If the ratio of loads is such that $X = 1.0$ and $Y = 0.0$, or $F_a/V\ F_r < e$, then formula (a) is used. If $F_a/V\ F_r > e$, formula (b) should be used.

For inner ring rotation $V = 1.0$ in all cases; for outer ring rotation $v = 1.2$, except for self-aligning bearings, where $V = 1.0$.

The X and Y factors are usually predetermined by the bearing manufacturer and will vary slightly. As a useful rule of thumb, the following values can be used. They are typical of the values given by the AFBMA (Anti-Friction Bearing Manufacturers Association).

$X = 0.56$ $\qquad$ $Y = 2.00$

Most of the instrument bearing catalogs contain nomographs which show the designer the life expectancy he desires. These nomographs take into consideration all of the factors mentioned above, although the actual presentation may vary slightly.

The American Standards Association has recently issued a new specification No. B11-1959 which standardizes the methods of computation.

ROTATIONAL SPEED REQUIREMENTS

As high speed ranges (over 50,000 rpm) become more common, increased attention will be given to operating

speeds because of their serious effect on bearing reliability. Rotational speeds up to 400,000 rpm are now being handled successfully by well-designed ball bearings.

A major problem with rotational speeds is fast reversals, which can cause the ball train to skid on the races. This skidding results in fretting corrosion, smearing of the base metals, and heavy "g" loads on the ball retainer. Although there is apparently no complete remedy for fretting corrosion, measures can be taken to minimize the problem. Adequate preloading of the bearing tends to keep the ball system in contact with the raceway, thus aiding the ball during reversing. Generous contact angles coupled with the preloading also help relieve the situation.

Some applications require bearings that do not rotate, but oscillate. This will shorten bearing life, since all of the loads are repeatedly applied over the same area. If the oscillations are rapid, problems identical to those caused by fast reversal as well as the wearing of a restricted area on the raceways are factors that have to be considered. A simple solution is to minimize the radial load. Preloading also helps for the same reasons mentioned above.

Uni-directional rotation results in maximum life for a given bearing, provided that radial and thrust loads are within the design limitations of the bearing.

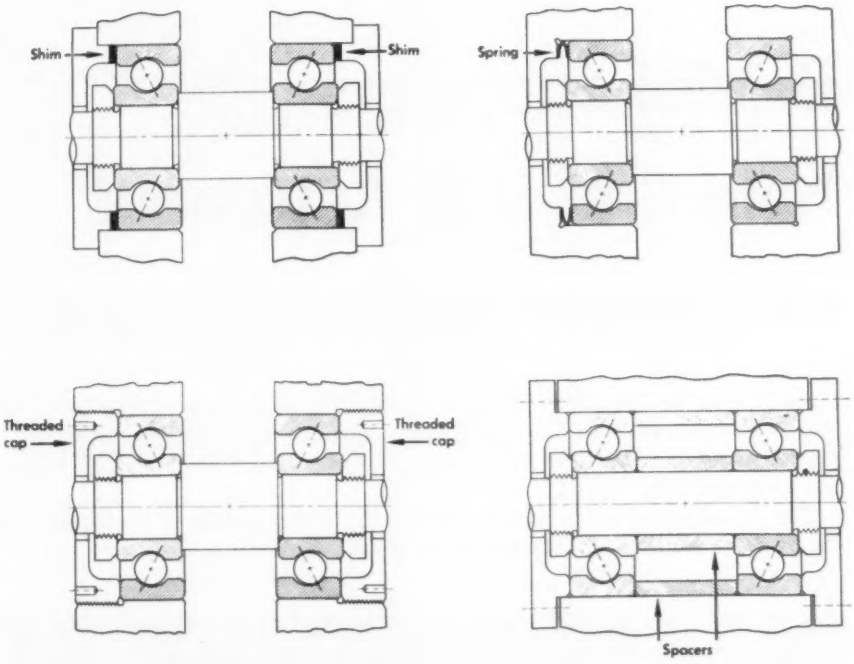
Another factor for review is the balance condition – static and/or dynamic – of the rotating mass of the assembly, i.e., flywheel, idler, etc. Unbalance is an additional cause of early bearing failure. As the speed of rotation increases, the effect of unbalance becomes more pronounced and bearing life is shortened.

RUN-OUT CHARACTERISTICS OF COMPLETED ASSEMBLY

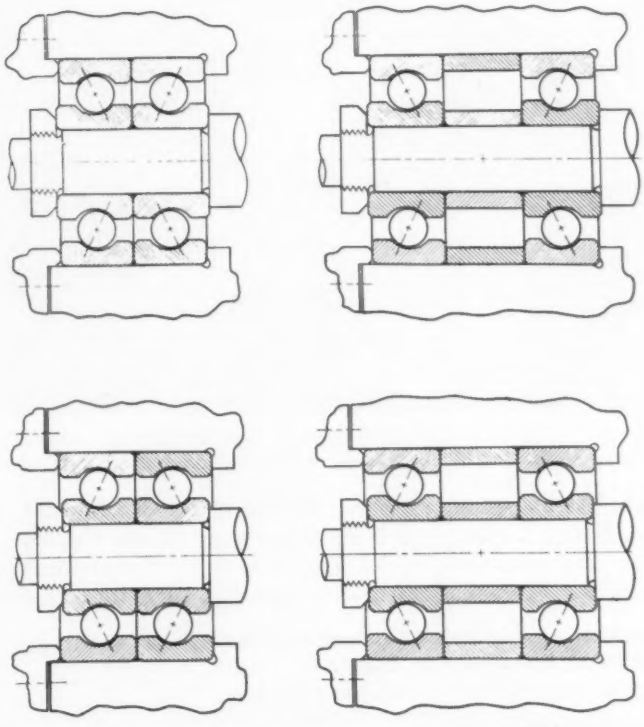
All ball bearings have definite run-out characteristics due to manufacturing processes. Only the instrument grades of bearings (ABEC Classes 1, 3, 5, and 7) have a maximum tolerance on the run-out of the inner and outer races. The higher the class number of the bearing, the less the amount of run-out. (Class 9 bearings have been built with a maximum run-out of only 20 millionths of an inch. However, these bearings are very special, and their cost extremely high.)

The run-out of the bearing can be used to control the concentricity of the outside diameter of the rotating assembly. Some run-out can be absorbed by preloading the bearing, since the side faces are usually more accurate dimensionally than the root of the raceway.

PRELOADING OF TWO BEARINGS ON A COMMON SHAFT

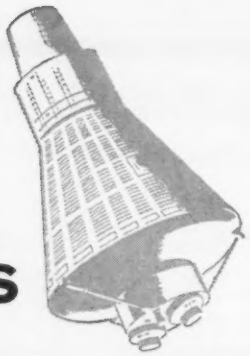


PRELOADING OF DUPLEXED PAIRS ON A COMMON SHAFT



Suggested ways of providing preload in precision assemblies.

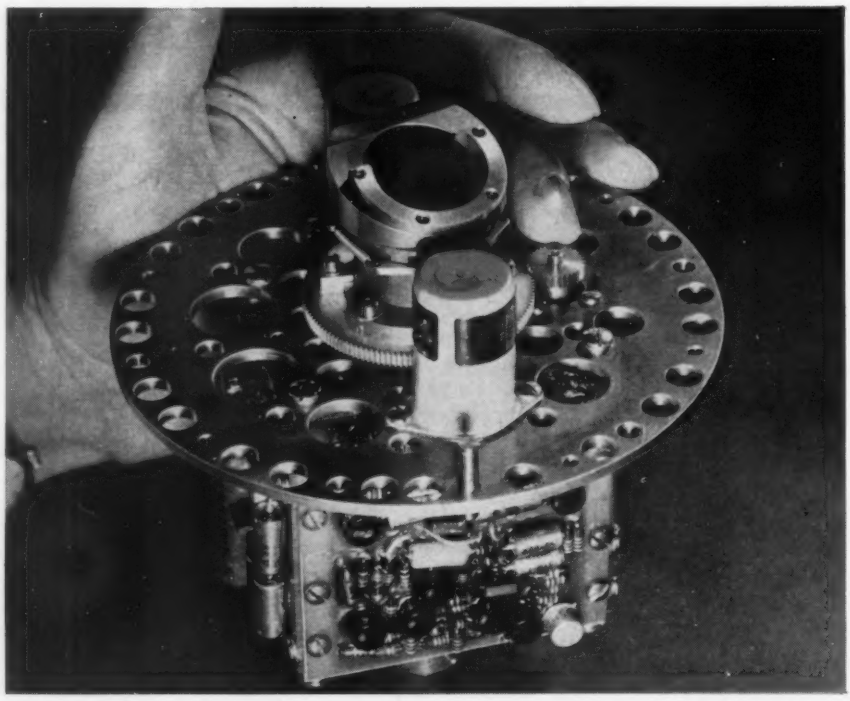
Courtesy of the Barden Corporation



Bristol choppers help first U.S. Astronaut maneuver space capsule

Four Bristol Syncroverter* choppers formed a vital part of the infrared horizon sensors manufactured by Barnes Engineering Company, Stamford, Conn., and carried aloft in NASA's MERCURY capsule by the first U.S. astronaut to reach outer space.

The Bristol choppers function as sensitive phase detectors in the sensors as they establish a horizontal reference plane for the vehicle.



Infrared Horizon Sensor undergoes rigorous optical, mechanical, and electrical checks at Barnes Engineering Co. One Bristol chopper is located in foreground, in front of gear.

Bristol Syncroverter* choppers, noted for low noise, long life and high reliability, are finding a vital place in more and more missile guidance systems, as well as in analog computers, d-c amplifiers, and test equipment for industrial applications. More than 200 models available. Write for complete details.

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DESIGN TIME SAVER

One of the accepted ways of removing run-out for a given rotating member is to have positive preloading on the bearings, and then grind the outside diameter of the assembly after the bearings and shaft have been installed. By using good quality instrument bearings and carefully controlled grinding, it is possible to lower the amount of the run-out to 50-75 millionths of an inch. This process is extremely difficult on a production basis, because the bearings must be kept completely clean during the operation. They cannot be removed for re-cleaning without losing the concentricity obtained by grinding.

Boundary dimensions of ball bearings, as well as other internal and external characteristics, are also defined in the ABEC Class 1, 3, 5, and 7. These dimensions are important in selecting correct housing and shaft sizes. Again, as the ABEC class number increases, the tolerances become tighter. For high precision components, the designer must use an instrument grade of bearing to achieve optimum results after assembly.

PRELOADING

To obtain maximum operational characteristics from ball bearings, they must be preloaded – all axial play removed by controlled thrust loading. Ball bearings may be purchased in preloaded pairs, and then installed either as a pair or separated by matched spacers. Single bearings or groups of bearings, all on one common shaft, may also be preloaded by the use of shims, spacers, springs, wavy washers or bowed washers. The accompanying diagrams illustrate some of the various methods of obtaining a preloaded condition.

The amount of preloading required is the minimal amount that will insure direct and positive contact of the ball train with the raceways. As the size of the bearing increases, so does the amount of preloading needed to produce contact. If excessive preloading is used, the balls will brinnel (permanently indent the ball groove of) the raceway, and the bearing will be noisy and tend to fail rapidly. A brinelled bearing is a total loss and must be replaced.

In preloading, correct radial clearance is necessary to achieve a realistic contact angle for the ball train and the outer race. Contact angles for preloaded bearings should be greater than 15°, but not more than 30°. There have been cases where a contact angle greater than 30° was used, but this

puts a gyratory force on the ball which then tends to rotate about an additional axis. Radial clearance or play is not covered by ABEC classification and must be specified if other than standard clearances are needed.

ENVIRONMENTAL REQUIREMENTS

Environmental conditions that will be present in the proposed application determine the material choice. Temperature of operational and standby cycles must be known, as well as coefficients of expansion and contraction of the bearing, shaft, and housing materials. A bearing tightly fitted in an aluminum housing subjected to temperatures of approximately −40°F would probably become inoperable since the contraction of the aluminum would cancel out the radial clearance within the bearing. Conversely, an assembly with a loosely fitted bearing in the same housing, subjected to 150°F, would probably develop a misaligned shaft as the bearing became increasingly loose. Therefore, the tolerances assigned to the bearing fits within the housing and on the shaft must be related to the properties of the materials.

Choice of material is usually determined by load requirements. Chrome steel (52100) bearings can withstand approximately 20% greater load than can bearings made of 440 C stainless steel. However, stainless steel bearings have better corrosion resistance. In some instances, it is necessary to provide bearings that are completely non-magnetic. Beryllium copper may be specified, although it has many limitations, such as susceptibility to galvanic corrosion, limited load-carrying capacity, and high starting and running torque.

Lubrication is closely related to environmental requirements of the completed assembly. Grease usually has a longer life, and provides a pseudo-fluid seal, but almost doubles the starting and running torque of the bearing. Oil is preferable for low torque.

SHAFT AND HOUSING MATERIALS

In addition to the requirement that shaft and housing materials have compatible expansion and contraction coefficients, they must be able to support the required loads. When a shaft or housing deflects, it causes misalignment of the ball-circles of the bearings. This misalignment shortens the life of the bearing, as well as causing noisy operation. If aluminum, magnesium, or some other housing material having a high coefficient of expansion is required, it is often advisable to provide a steel insert for the bearing seat. This insert can be installed using a heavy press fit, and then sized for proper bearing fit. The insert absorbs the expansion and contraction of the housing, giving the bearing a constant fit.

Shaft materials should be selected with care. Stainless steel (400 series), or a good grade of high carbon steel is preferred. For precision assembly, it is usually advisable to harden the shaft to 45-50 Rockwell "C", and to grind the bearing seats and other critical surfaces to the desired tolerances. When non-magnetic shafting is required, hardened beryllium copper or stainless steel of the 300 series may be used if the structural strength of the shaft has been determined, and matched with the application.

In all cases, the leading edge of the bearing seat, whether on the shaft or in the housing, must be chamfered at least 15°. All shoulders must be undercut to provide a square surface for the leading edges of the bearing. Finishes for bearing seats must be $\sqrt{16}$ or better.

PREVENTATIVE MAINTENANCE

The success of any rotating component, from a reliability standpoint, is a direct function of preventative maintenance. If such a component can be relubricated, adjusted, aligned, etc., after installation with a minimum of disassembly, the unit is well designed. Of prime importance is the maintenance of the lubricant. Normally, bearings should be re-lubricated after each five hundred hours of operation, in accordance with existing lubrication specifications. Over lubrication causes more bearing failures than lack of lubrication.

SHAFT AND HOUSING FITS

Instrument bearing dimensions, outside diameter and bore, have exacting tolerances determined by their ABEC class. If the designer uses the mid-point of the tolerance for the bearing under consideration, and then dimensions his shaft and housing using this mid-point, he follows the best accepted practice. Bearing manufacturers' quality control charts and bell-graphs indicate that this mid-point is an excellent guide post.

For miniature sizes of bearings, ODs up to and including 0.3750" fits that are line-to-line to 0.0002 loose on both the shaft and the housing are recommended. For other instrument bearings, the fits should be from 0.001 tight to 0.002 loose. If these tolerances are attained, the bearings will operate in the best possible manner, and maximum life and reliability will be achieved.

• • •

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"Ask Miss Arbogast to come into my office in exactly 7½ minutes."

HOW NEWTON DISCOVERED THE LAW OF GRAVITATION

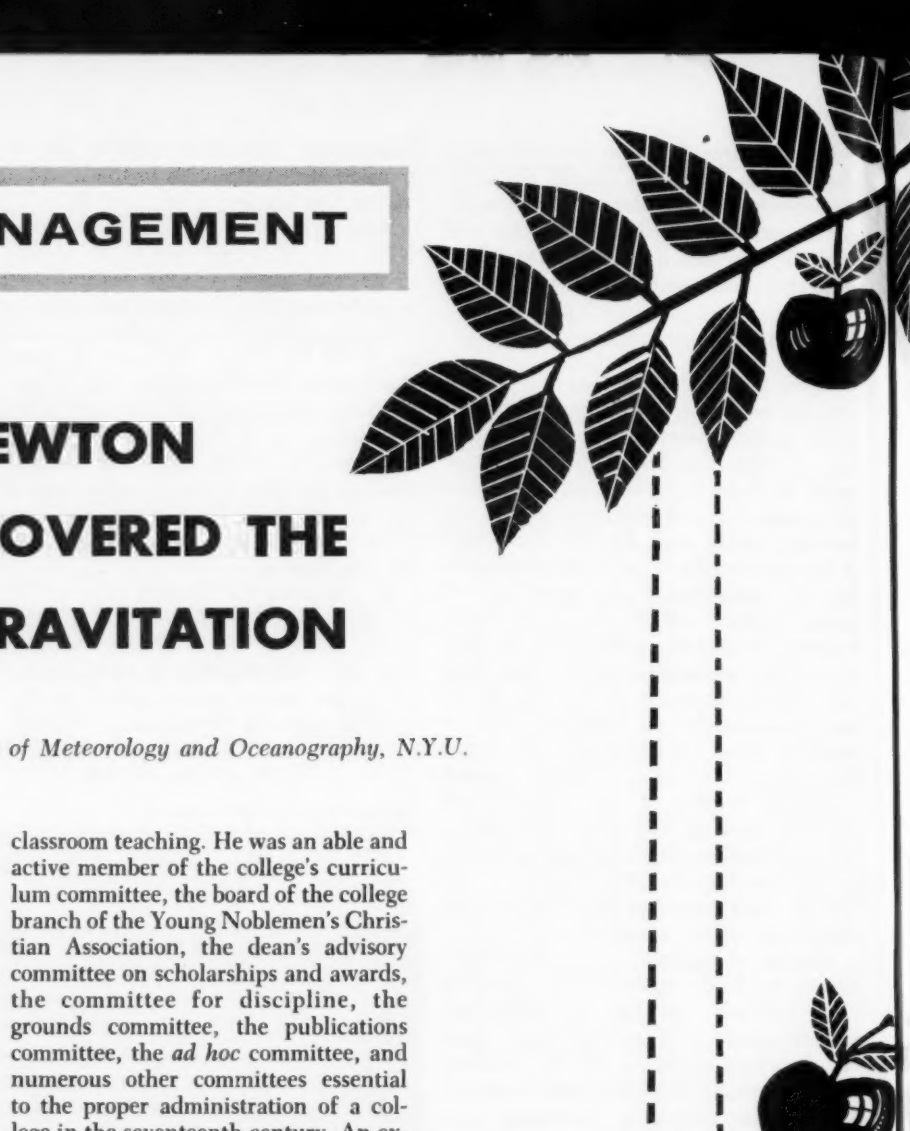
By James E. Miller, *Chairman, Department of Meteorology and Oceanography, N.Y.U.*

A tremendous increase in the number of vigorous young workers in the scientific vineyard has been one of the happiest results of the recent expansion, encouraged and nourished by our Federal Government, of scientific research in this country. These neophytes, left to their own devices by harassed research directors, have often found themselves without adequate guidance through the intricacies of governmental sponsorship; but, fortunately, they can find inspiration in the story of Sir Issac Newton, his development of the law of gravitation, and his experience as director of the Subproject for Apples of the Fruit-Improvement Project, sponsored by His Majesty's Government of Great Britain in co-operation with a syndicate of British fruit growers.

Few are familiar with the details of Newton's twenty-year search for a proof of his hypothesis: the frustrations and failures, the need for accurate measurements of the earth's radius and for a mathematical tool that Newton himself was forced to invent, and the integration of his scattered efforts by the splendid organization of the Fruit-Improvement Project. These details have been collected from his *Principia,* personal letters, notebooks and other papers, and a series of personal interviews arranged by a medium of the author's acquaintance.

In 1665 the young Newton became a professor of mathematics in the University of Cambridge, his alma mater. His devotion to his work and his capabilities as a teacher and friend of the student may be assumed without question. It is well to point out also that he was no dreamy, impractical inhabitant of an ivory tower. His services to his college went far beyond the mere act of classroom teaching. He was an able and active member of the college's curriculum committee, the board of the college branch of the Young Noblemen's Christian Association, the dean's advisory committee on scholarships and awards, the committee for discipline, the grounds committee, the publications committee, the *ad hoc* committee, and numerous other committees essential to the proper administration of a college in the seventeenth century. An exhaustive compilation of Newton's work along these lines reveals that, during a five-year period, he served on 379 committees, which investigated an aggregate of 7,924 problems of campus life and solved 31 of them.

Newton the genius was yet a human being; and though, in energy and ability, he far surpassed the great majority of his fellow men, he found himself ultimately limited in his powers. His unselfish devotion to the important work of his committees absorbed so much time that he was constrained to turn more and more of his teaching duties over to one of his students. He reasoned,



Originally published in the American Scientist, January 1951
Reprinted in N.Y.U. Engineering Research Review, April, 1961

Professor Miller is "now occupied in finding laboratory space and signing incomprehensible forms." He is co-author of "Workbook in Meteorology" and author of numerous technical papers.

quite correctly, that the substitution of a student as teacher in his place would benefit both the student and the student's students: the former because, in teaching, his own knowledge would be enhanced; and the latter because, in being taught by one near to them in age and interests, they would more eagerly grasp at the scraps of knowledge that came their way. Newton, whose stipend was small, did not spoil this idyllic arrangement by offering pay to his student substitute: a prime example of his sense of values and his restraint. Eventually, when his substitute had proved his ability as a teacher, Newton turned all the classroom work over to him and was thus able to channel all his tremendous powers into the administrative work of the college.

At about this time Newton, whose mind was too active ever to let scientific problems recede from his attention, occasionally mulled over the great discoveries of Kepler on planetary motions and the hypothesis advanced by a number of astronomers, that these motions were governed by an attraction that varied inversely as the square of the distance between planets. One evening of a crowded day in the year 1680, a committee that was scheduled to meet at eleven o'clock, no earlier time being available, was unable to muster a quorum because of the sudden death from exhaustion of one of the older committee members. Every waking moment of Newton's time was so carefully budgeted that he found himself with nothing to do until the next committee meeting at midnight. So he took a walk—a brief stroll that altered the history of the world.

It was on this excursion into the night air of Cambridge that Newton was struck by a flash of insight which set off a chain of events culminating in his announcement of the law of gravitation to the world in 1686. The season was autumn. Many of the good citizens in the neighborhood of the modest Newton home had apple trees growing in their gardens, and the trees were laden with ripe fruit ready for the picking. Newton chanced to see a particularly succulent apple fall to the ground. His immediate reaction was typical of the human side of this great genius. He climbed over the garden wall, slipped the apple into his pocket, and climbed out again. As soon as he had passed well beyond that particular garden, he removed the apple from his pocket and began munching it. Then came inspiration. Without prelude of conscious thought or logical process of reasoning, there was suddenly formed in his brain the idea that the falling of an apple and the motions of planets in their orbits may be governed by the same universal law. Before he had finished eating the apple and discarded the core, Newton had formulated his hypothesis of the universal law of gravitation. By then it was three minutes before midnight, so he hurried off to the meeting of the Committee to Combat Opium Eating Among Students Without Nobility.

In the following weeks Newton's thoughts turned again and again to his hypothesis. Rare moments snatched between the adjournment of one committee and the call to order of another were filled with the formulation of plans for testing the hypothesis. Eventually, after several years during which, according to evidence revealed by diligent research, he was able to spend 63 minutes and 28 seconds on his plans. Newton realized that the proof of his hypothesis would take more spare time than might become available during the rest of his life. He had to find accurate measurements of a degree of latitude on the earth's surface, and he had to invent the calculus.

Finally he concluded that he must find some relief from his collegiate administrative burdens. He knew that it was possible to get the King's support for a worthy research project of definite aims, provided a guarantee could be made that the project would be concluded in a definite time at a cost exactly equal to the amount stipulated when the project was undertaken. Lacking experience in these matters, he adopted a commendably simple approach and wrote a short letter of 22 words to King Charles, outlining his hypothesis and pointing out its far-reaching implications if it should prove to be correct. It is not known whether the King ever saw this letter, and he may not have, being overwhelmed with problems of state and plans for pending wars. There is no doubt that the letter was forwarded, through channels, to all heads of departments, their assistants, and their assistants' assistants, who might have reason to make comments or recommendations.

Eventually, Newton's letter and the bulky file of comments it had gathered on its travels reached the office of the secretary of HMPBRD/CINI/SSNBI — His Majesty's Planning Board for Research and Development, Committee for Investigation of New Ideas, Subcommittee for Suppression of Non-British Ideas. The secretary immediately recognized its importance and brought it before the subcommittee, which voted to ask Newton to testify before the Committee for Investigation of New Ideas. Some discussion of Newton's idea — whether it could really be called British in intent—preceded this decision, but the transcript of the discussion, filling several quarto volumes, clearly shows that no real suspicion ever fell upon him.

Newton's testimony before HMPBRD/CINI is recommended to all young scientists who may wonder how they will comport themselves when their time comes. His college consider-

ately granted him two months' leave without pay while he was before the committee, and the Dean of Research sent him off with a joking admonition not to come back without a fat contract. The committee hearing was open to the public and was well attended, though it has been suggested that many of the audience had mistaken the hearing room of HMPBRD/CINI for that of HMCEVAUC—His Majesty's Committee for the Exposure of Vice Among the Upper Classes.

After Newton was sworn to tell the truth and had denied that he was a member of His Majesty's Loyal Opposition, had ever written any lewd books, had traveled in Russia, or had seduced any milkmaids, he was asked to outline his proposal. In a beautifully simple and crystal-clear ten-minute speech, delivered extemporaneously, Newton explained Kepler's laws and his own hypothesis, suggested by the chance sight of an apple's fall. At this point one of the committee members, an imposing fellow, a dynamic man of action, demanded to know if Newton had a means of improving the breed of apples grown in England. Newton began to explain that the apple was not an essential part of his hypothesis, but he was interrupted by a number of committee members, all speaking at once in favor of a project to improve apples. This discussion continued for several weeks, while Newton sat in characteristic dignity waiting until the committee wished to consult him. One day he arrived a few minutes late and found the door locked. He knocked circumspectly, not wishing to disturb the committee's deliberations. The door was opened by a guard who told him there was no more room and sent him away. Newton, with his logical way of reasoning, deduced that the committee did not wish to consult him further, and forthwith he returned to his college and his important committee work.

Several months later Newton was surprised to receive a bulky package from HMPBRD/CINI. He opened the package and found it contained a variety of governmental forms, each in quintuplicate. His natural curiosity, the main attribute of the true scientist, provoked him into a careful study of the forms. After some time he concluded that he was being invited to submit a bid for a contract for a research project on the relationship between breed, quality, and rate of fall of apples. The ultimate purpose of the project, he read, was to develop an apple that not only tasted good but also fell so gently that it was not bruised by striking the ground. Now, of course, this was not what Newton had had in mind when he had written his letter to the King. But he was a practical man and he realized that, in carrying out the proposed project, he could very well test his hypothesis as a sort of sideline or by-product. Thus, he could promote the interests of the King and do his little bit for science in the bargain.

Having made his decision, Newton began filling out the forms without further hesitation. One of the questionnaires asked how the funds allotted for the project were to be spent. Newton was somewhat taken aback to read that £12,750 6*s*. 3*d*., the surplus remaining in the horticultural development fund for the current fiscal year, had been estimated as the total cost of his project. Methodically, he put down his own stipend first, and after a moment's thought he added the item: "Other salaries, travel, supplies, and overhead: £12,750 0*s*. 0*d*."

A true believer in correct administrative procedures, Newton sent the completed forms by special messenger to the Dean of Research, for transmittal through proper channels to HMPBRD/CINI. His adherence to established procedure was rewarded a few days later when the Dean of Research summoned him and outlined a new plan, broader in scope and more sweeping in its conception. The Dean pointed out that not only apples but also cherries, oranges, lemons, and limes fell to the earth, and while they were about it they might as well obtain a real, man-sized government contract to cover all the varieties of fruit that grow above the ground. Newton started to explain the misunderstanding about the apples but he stopped rather than interrupt the Dean, who was outlining a series of conferences he proposed to organize among fruit growers and representatives of various departments of His Majesty's Government. The Dean's eyes began to glaze as he talked, and he became unaware that anybody else was in the room. Newton had an important committee meeting at that time, so he quietly went out the door, leaving the Dean of Research in an ecstasy of planning.

The seasons passed, while Newton led a busy, useful life as a member of many committees and chairman of some. One dark winter's day he was called again to the office of the Dean of Research. The Dean was beaming; he proudly explained to Newton all about the new contract he had obtained to study the relationship between breed, quality, and rate of fall of all the varieties of fruit that grow above the ground. The project was to be supported by no less than five different branches of His Majesty's Government plus a syndicate of seven large fruit growers. Newton's part in the project was to be small but important: he was to direct the Subproject for Apples.

The following weeks were busy ones for Newton. Though relieved from his committee work (a young instructor of Greek, Latin, history, and manual training took his place on the committees), he found himself cast into a morass of administrative problems: forms to be filled out for the governmental departments, for the fruit growers, for the Dean of Research, for the Assistant Dean of Research, and for the financial office of the college; prospective research assistants to be interviewed and hired; office and laboratory space to be wangled from other projects on the campus. The wide abilities of our great genius are fully demonstrated by the way he piloted his subproject during its first formative weeks. He personally filled out 7,852 forms, often in quintuplicate and sextuplicate; he interviewed 306 milkmaids and hired 110 of them as technical assistants. With his own hands he cleaned out an abandoned dungeon in a nearby castle for use as subproject headquarters; and, turning carpenter in typically versatile fashion, he erected twelve temporary buildings to house his staff. These buildings, used today as classrooms, stand as a monument to Newton's career.

Soon the subproject was fully implemented, documented, and regimented. Newton was not quite sure what his reconverted milkmaids could do for his hypothesis (he was a lifelong bachelor and hence not well acquainted with the ways of women), but he abhorred the thought of idleness in his staff. So he divided them into six teams, each of which was to measure and tabulate the rate of fall of one variety of apple, using sufficient apples to establish a statistically significant result. All went well except with the winesap team, who discovered a new way of making applejack, and consequently ran short of apples. Newton made a note of their recipe, wisely comprehending long before his fellow scientists the advantages of serendipity, or finding good things while looking for other things.

This period of his life was a happy and profitable one for Newton. From the time he arose in the morning until, exhausted with honest labor, he dropped late at night back into his humble bed of straw, he spent each day filling out payroll forms for his milkmaids, ordering pens and paper, answering the

questions of the financial office, and showing distinguished visitors and the Dean of Research around his subproject. Often he discussed the past, present, and future work of his project with representatives of the five governmental departments and seven fruit growers who had been sent to check on his progress. He was frequently invited to give progress reports in person at the central offices of these twelve sponsors. Each week he wrote out a full progress report which was duplicated and sent by special messenger to 3,388 other projects sponsored by His Majesty's Government throughout the British Isles.

One of these remarkable documents, in an excellent state of preservation, can be found in the Museum of the Horticultural Society of Western Wales, in the village of Merthyr Tydfil. In typically logical style, the report, bound in a dark red stiff cover bearing the project number, HM2wr3801-g-(293), stamped in gold leaf, opens with a succinct table of contents:

1. Administration
2. Conferences
3. Correspondence
4. Supplies
5. Results of research

The last section, "Results of research," may have been lost during the intervening years, or it may not have been specifically required under the terms of His Majesty's contracts of that era. At any rate it is not there. But the other sections remain to gladden the hearts of those permitted to read them. Is it too much to hope that this report can be published and distributed among our young scientists in America? Such a precept should accomplish miracles for the morale and spirit of our neogeniuses.

One day in 1685 Newton's precise schedule was interrupted through no fault of his own. He had set aside a Tuesday afternoon to receive a committee of vice presidents of the fruit growing syndicate when, much to his horror and Britain's deep sorrow, the news spread that the whole committee had been destroyed in a three-stagecoach smashup. As once before, Newton found himself with a hiatus. He took a leisurely walk through the luscious vineyards of the Subproject on Grapes, but not, of course, until he had obtained security clearance at the gate. While on this walk there came to him, he knew not how ("Ye thought just burst upon me," he later wrote), a new and revolutionary mathematical approach which, in less time than it takes to tell about it, could be used to solve the problems of attraction in the neighborhood of a large sphere. Newton realized that the solution to this problem provided one of the most exacting tests of his hypothesis; and furthermore, he knew, without need of pen and paper to demonstrate the fact to himself, that the solution fully supported his hypothesis. We can well imagine his elation at this brilliant discovery; but we must not overlook his essential humility, which led him forthwith to kneel and offer thanks to the King for having made the discovery possible.

On his return from this walk, Newton stopped a moment to browse in a bookstore, where he accidentally knocked a book to the floor. With apologies to the proprietor, who seemed in a mood to toss him out upon his ear, Newton retrieved the book and dusted it off. It was Norwood's *Sea-Mans Practice*, dated 1636. Opening the book at random, Newton found it contained the exact information on the length of a latitude degree that he required for the complete test of his hypothesis. Almost instantaneously, one part of his brain performed several lightning calculations and presented the result for the other part to examine; and there it was: the proof complete and irrefutable. Newton glanced at the hourglass in the shopkeeper's window and with a start remembered that he was due back at the dungeon to sign the milkmaid's time slips as they checked out for the day. He hurried out of the bookshop with the book under his arm, forgetting in his zeal that he had not paid for it.

Thus it was that His Majesty's Government supported and encouraged Newton during the trying years in which he was putting his hypothesis to the test. Let us not dally with the story of Newton's efforts to publish his proof, the misunderstanding with the editor of the *Horticultural Journal*, the rejections by the editors of *The Backyard Astronomer* and *Physics for the Housewife*. Suffice it to say that Newton founded his own journal in order to make sure that his proof would be published without invalidating alterations. Regrettably, he named his journal *Star and Planet*, with the result that he was branded a subversive since Star could mean Red Star and Planet could mean Plan-It. Newton's subsequent testimony before the Subcommittee for Suppression of Non-British Ideas remains as a convincing demonstration of the great qualities that combined to make him a genius. Eventually he was exonerated, and after enjoying many years of the fame that was due him, reigning one day each year as King of the Apple Festival, Newton died happily.

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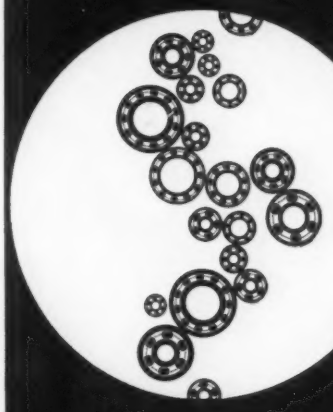

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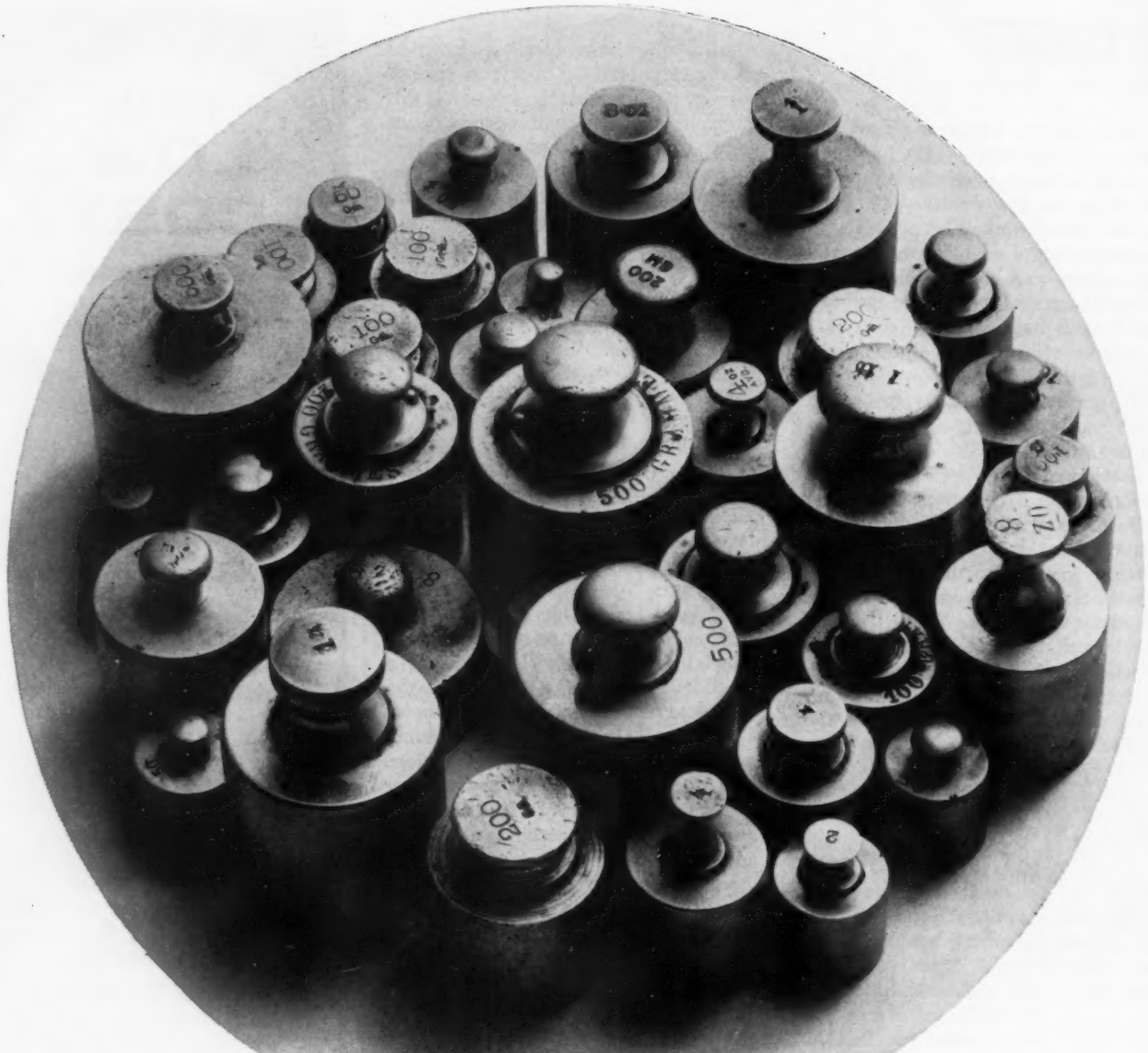

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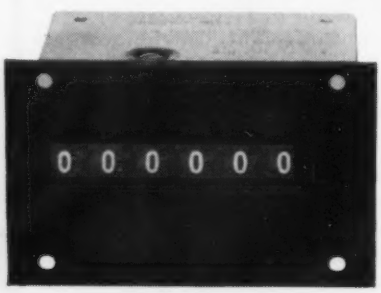

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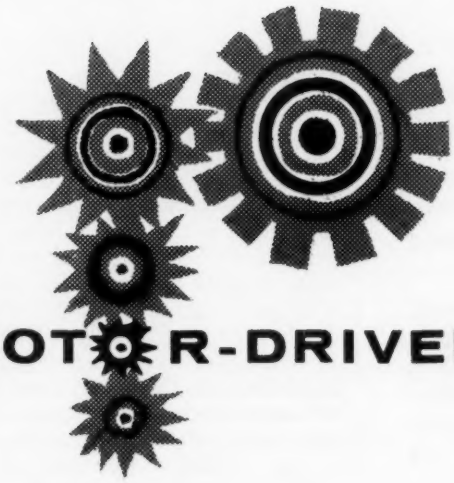
COMPONENTS DIGEST 20

PART III



MOTOR-DRIVEN TIMING DEVICES

A constant speed motor driving a cam shaft mechanism for switch actuation constitutes one of the most versatile electromechanical systems for the timing of events. Basic accuracy depends primarily on the motor, as discussed in a previous installment of this series. For reasonably long periods, more than 10 seconds say, accuracy will depend on the constancy of motor speed as line voltage, frequency (in ac systems) temperature loading, and other operating conditions change. Accuracies to a small fraction of a percent can usually be achieved where required. For initial intervals in the order of several seconds, the time necessary for motor acceleration may become an important factor. Motor driven timers are not recommended for accurate timing where motor acceleration time is a significant portion of the timing interval.

For extremely long timing intervals (hours, days, or even weeks) motor driven timers are ideal. All that is required is a sufficiently large gear reduction from motor to output shaft. An ordinary electric clock will drive its hour hand at a rate of 2 revolutions every 24 hours (and incidently, at very high accuracies). Although enormous gear ratios are involved, the gearing is generally required to exert very light torques, and because of the uni-directional character of the drive, backlash is probably not an important consideration. Except in military applications, the cheapest grades of gearing are usually satisfactory.

OUTPUT MECHANISMS

At the output shaft the most common indication is the actuation of control switches by cam-like mechanisms. The variety of such mechanisms is enormous, depending upon such factors as the complexity of the switching circuits, the need for compactness, and many other special considerations. In a simple arrangement a conventional plate cam may actuate a limit switch. In more complex systems a large drum with pin inserts may program a series of events. In all cases, additional relays may be used in association with the direct output to initiate more complex events.

It is usually desirable to use snap-acting switches rather than those types where contact is established gradually at a rate corresponding to the shaft output speed. In particular, where a slowly rotating output shaft must cause a heavy power circuit to be closed, a gradually closing (or opening) contact can lead to arcing and contact destruction. This also may be a consideration where the contacting mechanism consists of an arrangement of a printed circuit board and brushes. Current ratings in this type of circuit must be substantially reduced below those values which could be tolerated in snap-action type switching.

Snap acting switches used in conjunction with a timer are best set on a trial and error basis. The precise switching point is somewhat indefinite, and is not accurately known strictly on the basis of switch geometry. Further limitations are inherent in the cam geometry. Wear of cam or limit switch surfaces introduces further errors. It is not wise to rely on a repeatability of better than several thousandths in estimating timing accuracy. Further geometric shifts may result from changes in the switch operating point with such factors as contact wear, or operating temperature. These factors must be reviewed in consultation with the switch manufacturer.

There are many practical variations on the basic system described above. Where trial and error adjustment of the switch actuation point is required, it is desirable to be able to decouple the gear train from the output mechanism so that it is not necessary to drive the gear train backwards which is generally a bad practice. A zeroing adjustment may be provided for setting up the reference point when gear train and mechanism have been recoupled. Dials may be provided to facilitate the actual setting up of operating points.

TIMING CYCLES

Depending upon the use to which the timer may be put, there are various means of starting the cycle, repeating the cycle, etc. Consider again the simple motor-driven switching mechanism. When this is energized the cycle will be started. If at any time during the cycle, power is interrupted, the timer will simply stop and remain at its location at the time of the interruption. Restoration of power leads to a continuation of the timing cycle.

At the conclusion of the timing cycle, there are many possibilities. The motor may simply continue to rotate and repeat the sequence. Or it may disconnect itself as the very last switching event in the sequence. In this instance, starting up the cycle may be readily accomplished by a simple pushbutton actuation which temporarily by-passes the disconnect, or by any of a great variety of simple me-

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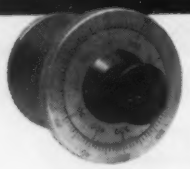

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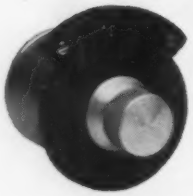

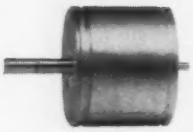

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COMPONENTS DIGEST

chanical or electromechanical resetting mechanisms.

It may be desirable to provide a nearly instantaneous reset on command. One way of accomplishing this would be to incorporate a clutching mechanism between gearhead output shaft and the switching mechanism. A restoring spring on the switching mechanism would exert a force so directed as to drive the switching mechanism directly to zero in the absence of the gear train drive. If the coupling clutch were magnetically actuated to provide positive coupling when energized, then the timing sequence could be easily reset to zero by a momentary interruption of the clutch energizing current. If desired this reset function could be carried out automatically by means of the last switching event of the timing sequence. Power failure would automatically restore the zero point. If a normally coupled clutch which becomes decoupled upon disconnecting power were employed, other possible timing events could be brought about.

COMPLEX DEVICES

Several output shafts rotating at different speeds to increase the flexibility of setting up timing events could be provided. Independent timing motor drives might be interconnected. For example, if it is desired that an event occur precisely one minute after an initial event which itself had been delayed say four hours, then the four-hour timing event could result in the actuation of a faster timer which delivered high accuracy for timing intervals measured in minutes.

Actually the variety of timing mechanisms and systems is so great that it is impossible to cover them all in a reasonably compact presentation. The system designer must cooperate with the timing manufacturer in choosing the best "combinations" for solving his problem.

A. W. Haydon recommends that a complete problem statement, submitted to the manufacturer, should include: a description of the application, circuit diagram, and chronological sequence of events which are to occur. The method of initiating timer operation should be described, as for instance, — momentary contact closure of a relay or switch. Environmental conditions should be listed together with voltage range and any special requirements which might influence timer design.

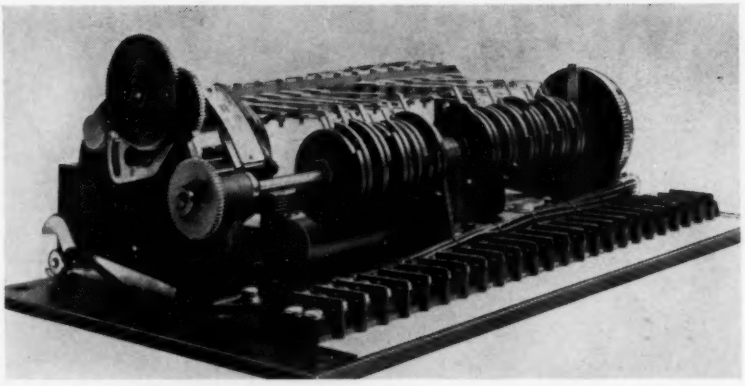

Fig 1 Series 2400 Multi-circuit cam timer from Automatic Timing & Controls. Powered with a synchronous motor, the timer is rated for operation from 110 or 220 volts, ac. (other voltages available). Motor drives a cam-shaft thru a gear train designed to rotate the shaft at a desired rate. Precision-cut split cams, mounted on the shaft, may be adjusted to actuate either silver or mercury control circuit contacts. All wiring is accommodated on clearly marked screw-post terminal block. Telechron motor lubricated for life; shaft bearings Oilite, no lubrication required. All parts are easily accessible.

The tendency to modular breakdown of the basic ingredients (motor, gearing, and switching mechanism) and even the sub-components such as switches and clutches, makes it relatively easy to put together special purpose variations.

The following section presents detailed descriptions of commercially available motor-driven timers. Units were chosen to illustrate variations of types available and are not intended to cover the field.

Automatic Timing & Controls

Multi-circuit cam timers, from Automatic Timing & Controls, King of Prussia, Pa., offer a simple means for accurately controlling the sequence and duration of one or a series of individually timed operations. Any number of load circuits may be controlled; the time for total cycle may be simply altered; duration of "made" and "broken" periods as well as sequence of each operation may be easily changed.

Built from standard parts, the Series 2400 flexible timer, shown in Fig 1, may be specified by the user in exact accordance with operating requirements for specific applications. By using various motors, time cycles from ⅔ of a second to 7 or more days are available. Precision cut cams can be adjusted to actuate either silver or mercury control circuit contacts.

Four basic operating characteristics of ATC's Series 2400 timer are:

- Repeat cycle – timer runs continuously until power is interrupted.
- Stop cycle – timer motor connected in series with cam operated switch so that upon closing of external start switch for 1% of total cycle, the timer runs through one shaft revolution and stops.
- Long cycle – similar to stop cycle, except miniature relay permits stop cycle operation from a momentary start signal; eliminates need for holding starting contact closed.
- Brake – stop cycle with a dynamic braking system to ensure quick stopping without coasting or fast time cycles.

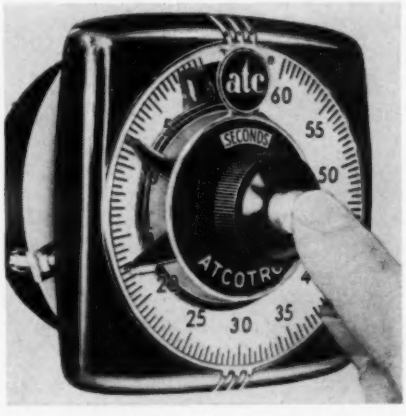

Fig 2 Automatic Timing & Control's 309 interval timer automatically resets by pushbutton.

One special model of Series 2400 timers incorporates poppet valves, rather than electrical contacts, for pneumatic control of diaphragm valves, air cylinders or air relays. Repeat accuracy is ½ of 1%.

Featuring a built-in pushbutton for starting automatically timed control of electrical circuits, ATC's Series 309 Dial Timer, for industrial process, laboratory and machine automation, is a synchronous motor-driven unit for control of ac or dc loads within variable timed intervals or sequences. Unit is shown in Fig 2.

Setting desired cycle time is made easy by large knurled knob. Upon completion of timed cycle, timer automatically shuts off and resets. Operation is repeated by simply pushing the button. On power interruption, timer does not reset; indicating pointer remains in position. Upon power resumption unit resumes timing out balance of preset time cycle.

Automatic Timing and Controls Co. makes a complete line of timing devices. Their instruments are constructed so they can be integrated with their control devices for compact systems design.

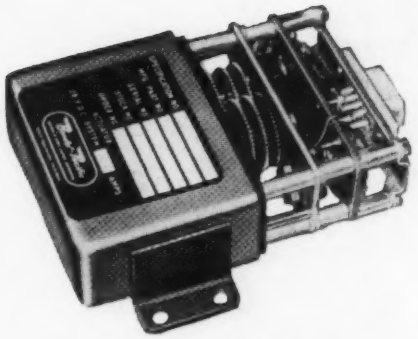

Fig 3 Bendix-Pacific's universal timer incorporates a dc motor driving a gear train which operates rotating cams and limit switches or printed circuit wafer switches. Motor operates on 28 vdc — 15 watts — accuracy to within 1% with voltage regulation; 5% without. Unit weighs approx. 8 oz. including motor, gear train and one timing module.

Bendix-Pacific

Driven by special constant speed motors, a universal timer (Fig 3), by Bendix-Pacific, No. Hollywood, Calif., incorporates a modular gear construction permitting gear selections which are applicable to practically any timing range. Designs are available which vary from simple time-delays of a few seconds to extremely complex sequencing devices having total cycle times of several hours.

Gear train can be supplied with dual output shafts, rotating at any desired speed ratio. These outputs can then be used either independently or interacting to provide reliable mechanical control of one circuit over another. Many standard timing modules are available, including wafer switches, snap switches, variable inductors, capacitors or resistors, printed circuits or combinations of these.

Small reliable reset clutches can also be provided for automatic or manual resetting of a portion or the total cycle time. These clutches are sometimes also used to vary the speed or mode of operation.

Accuracy and repeatability of the time delay can be held to approx. 1% through a fairly wide temperature change and line voltage variations.

COMPONENTS DIGEST

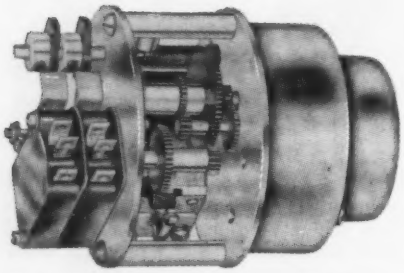

Fig 4 Specifications for Bristol Motors' TDR-100 time delay relays include: time setting — from 15 sec. to 3 months full scale, based on 270° full scale setting; reset — instantaneous and well under 1/5 sec.; size — 3" long and 2½" diam. (approx.); rating — non-inductive load of 10 amp and a 5 amp inductive load; voltage—115 volts ac, 60 cycle standard.

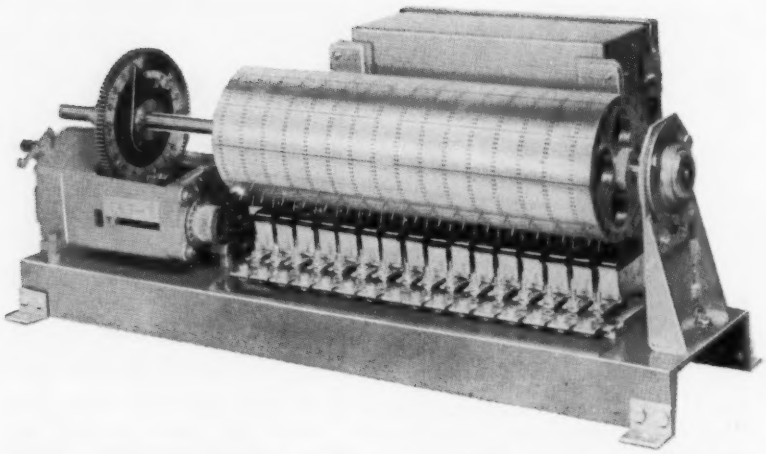

Fig 6 Counter & Control Corp's adjustable program timer for continuous cycling. Units may have any time cycle up to 66⅔ minutes, max. Range brackets are specified in 100-second increments. Overall time cycle settings may be adjusted in 1 second increments from 0 to ½ max. range, and in 2 second increments from ½ to max. range. Intermediate switching events can be preset at any points throughout the full range in 1-second increments. Number of intermediate switching events is limited only by the length of the time cycle setting; the maximum would be 1 per second. On a 60 cycle line, switching accuracy can be held within plus or minus 1/10 second. Any switching program is recycled automatically and indefinitely without pause or skip between cycles.

Bowmar Instrument

Subminiature, hermetically-sealed, elapsed time indicator, by Bowmar Instrument Corp., Fort Wayne, Ind., provides continuous digital readings from 0000 to 9999 hours, with return to 0000, in increments of one hour. You can read it instantly, easily and reliably from a distance of up to 6 feet. Size of the unit is 0.670 inches in diameter (nominal) and 1.680 inches in length (max.) Weight is approx. 1.8 oz. Environmental requirements of Mil-M-26550A (USAF) are met.

Bristol Motors

For general timing applications requiring the instantaneous reset-type of action, Bristol Motors', Old Saybrook, Conn., time delay relays are a combination of their standard motor, a solenoid-operated differential-type clutch, and enclosed snap-action switches. The unit is shown in Fig 4. Better than 1,000,000 cycles may be expected. Quick reset time is well under 1/5 second with a high repeat accuracy of better than 1% of full scale.

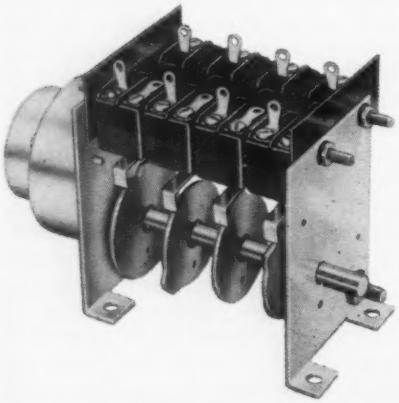

Fig 5 Bristol Motors' repeat cycle timer contains enclosed snap action switches with solder terminals. Size is 2½" wide, 3" high, 1½" long plus about 11/16" for each switch.

Bristol's repeat cycle timer shown in Fig 5, is a multi-contact unit used where repeat accuracy is required. Speed ranges from 1 revolution per sec. to 1 rev. per month, with standard, high torque or reversible motors. Wide variety of cams and switch combinations are available.

The basic precision timers made by Bristol can be modified, expanded or combined to meet many timing requirements. Bristol also produces special timers to individual specs.

Counter and Control

By applying a synchronous motor drive to its Programonitor, the Counter and Control Corp., Milw., Wisc., is able to offer a repeat cycle program timer with unusual range, flexibility and a fine degree of adjustment. As normally used, the Programonitor is a recycling, circuit-controlling counter which responds to mechanical or electrical inputs of variable speed. With a constant speed drive, as illustrated in Fig 6, it becomes a timer.

This arrangement permits the programming and recycling of complex switching patterns with respect to a time base. Although the unit features positive, automatic recycling, it does not sacrifice selection and adjustment of range settings. The overall time cycle is adjustable over the entire range of the unit. The accuracy of any intermediate switching points selected is unaffected by the length of the overall time cycle or their position in the cycle.

Cramer Controls

Equally applicable as a remotely

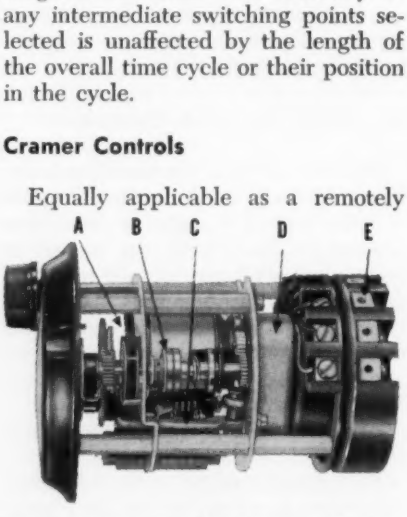

Fig 7 Cramer Controls' Type 412 automatic reset interval timer also used as a time delay relay. A. Reset spring, 30 inches long, wound on large diameter drum. Pre-loaded semi-rigid design absorbs reset shock and returns to exact position after each operation. B. Positive ratchet clutch has 60 gear teeth, firmly meshed by powerful solenoid. C. Extra-heavy, open-blade silver-cadmium-oxide contacts handle high inrush currents. D. Permanent magnet motor provides instant start, synchronous operation with no coasting on removal of power. E. Rugged barrier-type terminals allow connections from either front or side. Repeat accuracy of the timer is within ¼ of 1% full scale on 30 second and longer ranges.

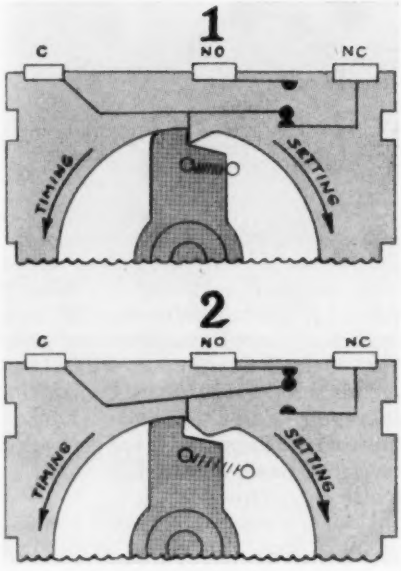

Fig 8 In Cramer Controls' Type 271 interval timer, the cam mechanism incorporates a spring loaded reversing pawl that provides 'drop-off' (1) for fast contact transfer at end of cycle, and allows gradual rise (2) for setting operation.

controlled, automatic reset interval timer and as a time delay relay, Cramer Controls' Type 412 unit offers great flexibility. Common uses include the control of machine tools, batch processes, heat treating and automatic mixing equipment.

Type 412, illustrated in Fig 7, is a panel mounted instrument with full scale adjustability. Rotating the friction setting knob locates both pointers — to any point on the dial. Three contact arrangements are available, the choice determined by the desired position of the load switch in the before-during-after timing conditions. Each of the three mechanisms can be controlled from either a momentary or sustained external contact.

Reset may be either automatic on completion of timing, or delayed until the starting impulse for the next operation is received. Cramer's Type 422 is similar to Type 412, except for "reverse-clutch" action. In Type 422, the clutch coil is energized only during reset. Timing is initiated by closing the clutch circuit momentarily (½ sec). Power interruption simply causes Type 422 to suspend operation and continue timing when the circuit is restored.

Cramer's Type 742 Duplex consists of two standard 412 timers, in series in a common housing, to provide widely different intervals. Each timer is independently adjustable — controls its own load, then automatically energizes the other timer. Range is 60 combinations from 6 seconds to 24 hours.

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In addition to high accuracy the instrument combines a number of other prominent advantages: it requires only a single power source; it has good sensitivity; it is designed for modular application; and it offers direct automatic readout. The unit is of extremely compact construction and is built for maximal ease of maintenance.

The low-cost CO 2721011 Precise Angle Indicator is available with a single sensor, auxiliary dual-input sensor, or an auxiliary retransmitter. For additional information on this new test instrument, write for the brochure which describes its operation and capabilities in detail.

SPECIFICATIONS

Repeatability	±1.2 min	**Slewing Speed**	7 sec/180°
Readability	0.5 min	**Power (single source)**	115 v, 1φ, 400 cps
Input Power	30 va	**Size**	1¾ x 9½ x 9⅛ in.
Sensitivity	1.0 min	**Weight**	4 lbs.

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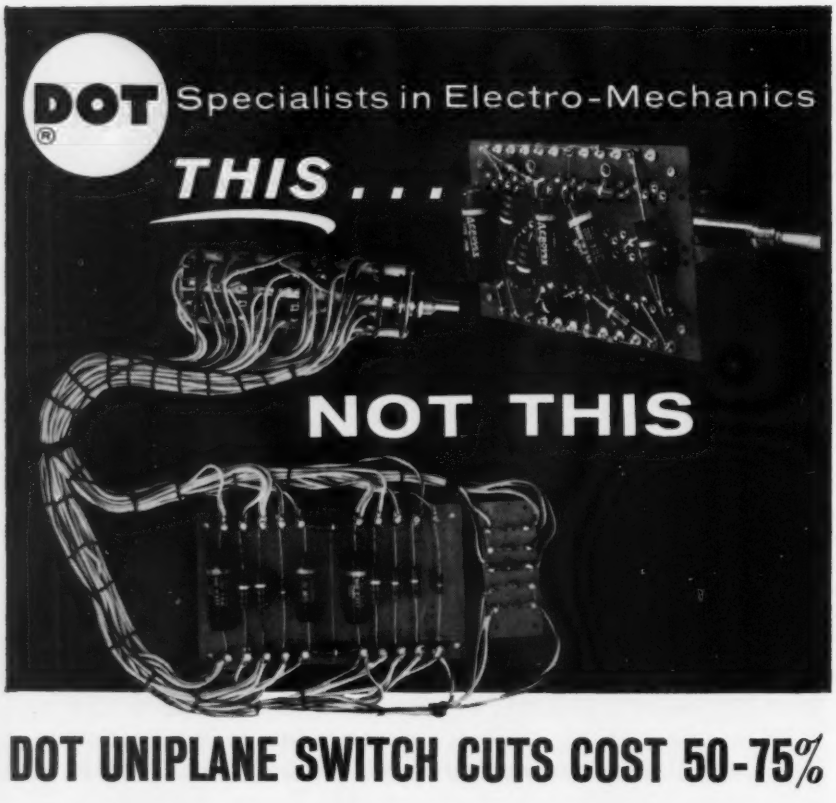

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COMPONENTS DIGEST

Designed primarily for built-in applications, Cramer's Type 271 is a low cost, compact, manually set interval timer. High torque motor (30 inch ounces at 1 rpm) assures instant starting. Overall accuracy is within ½% of full scale, exclusive of human setting error. Large, precision-cut Bakelite cams incorporate a spring-loaded reversing pawl, illustrated in Fig 8, for snappy response.

Cramer Controls, located in Centerbrook, Conn., also makes a full line of hermetically sealed timers that meet stringent Mil specs. Expected minimum life of the ac units is 10,000 hours or 50,000 operations.

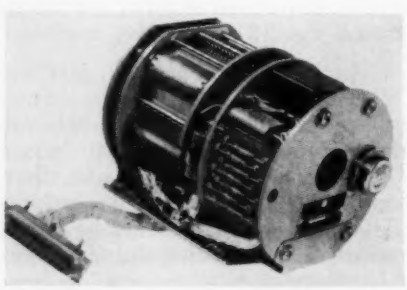

Fig 9 Precision program timer for space vehicles from Designers for Industry, Inc. Test units are still performing without failure after 5,000 hours' operation.

Designers for Industry

A precision program timer for space vehicles is made by Designers for Industry, Inc., Cleveland, Ohio. The unit, shown in Fig 9, is fully qualified to Mil specs without deviation. Program is stored on a punched steel tape – only short perforations are necessary – one turns a circuit on, another turns it off. Unit is accurate to ±1/100 second over spans up to 15 minutes with longer spans available.

Approximately 25 watts maximum power from 28 volt battery source, with all relays energized, is required. Time accuracy is controlled by a temperature-stabilized 25.6 KC crystal oscillator, output of which is divided to 400 cycles, then amplified by power transistors to drive a synchronous gear motor. This specially designed reversible gear motor with integral clutch brake drives a stainless steel tape which has a number of information channels for pitch command – telemetering and control of other unique functions.

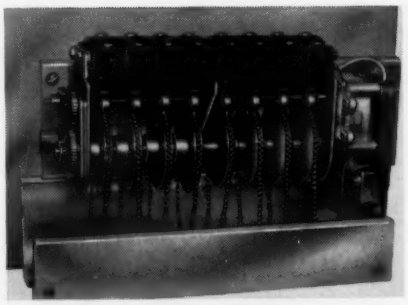

Fig 10 Eagle Signal Co.'s bead chain timer in which the cam was removed and replaced with a drive sprocket. Beads on a stainless steel chain actuate switch at desired time.

Eagle Signal

In their bead chain timer, Eagle Signal Co., Moline, Ill., has removed the cam and replaced it with a drive sprocket, in which an endless stainless steel bead chain (not unlike the key chain in your pocket) is advanced (Fig 10). To establish the cam action which actuates the switch at the desired time, large beads are applied to the chain. These beads may be applied singly to give a momentary closure or in groups to produce a sustained closure. Varicolored beads are used for coding. There is virtually no limit, according to the company, to the length of chain or timing ranges.

The company says that this seemingly elementary idea has solved problems that could only be solved previously with complex expensive equipment. For example, by applying a "Digimotor" as a solenoid drive mechanism to replace the synchronous motor, an omitter or interrupter is established. Such a mechanism has already been produced which will omit any complete day or days from an otherwise uninterrupted yearly programmed schedule. The bead chain timer is not yet an entirely standardized and catalogued item; it is available, at this time, on a semi-custom basis.

Elgin Micronics

For high shock and high altitude applications where weight, size and power draw are critical factors, Elgin's Model 16B, direct current elapsed time indicator weighs less than 1¾ ounces, is 0.680″ in diameter by 2.02″ long, and draws less than 60 milliwatts of power. Tested in accordance with Mil-M-26550 and MS-24534, units are ruggedly constructed with solid state circuitry. With the exact life data provided by Elgin, teardowns and replacement schedules can be based on real rather than estimated needs. Specifications for the 16B include: accuracy, ±5%; electrical rating, 28

SPECIAL PURPOSE PRECISION BEARINGS FROM KEARFOTT

Highest quality, special purpose precision bearings are now available from Kearfott Division, General Precision, Inc. for military and industrial applications requiring utmost reliability, accuracy and stable performance. Over 10 years of research, testing and development have gone into the production of these outstandingly reliable, precision bearings.

Designed to meet the most exacting systems standards, these special purpose precision bearings have more than passed the test of time, delivering long life performance for Kearfott gyros, instruments and other critical airborne equipment. Engineering and technical excellence derived from long experience enables Kearfott to ensure delivery of bearings that provide unsurpassed qualities of roundness, concentricity, curvatures, finish, dimensions and functional tolerance.

Special purpose, high precision bearings from 0.3125 to 4.5 inches O.D. are now ready for production delivery in a wide range of application types including—

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- **STABLE PLATFORM GIMBALS**
- **GYRO PRECESSION AXES**
- **OTHER SPECIALIZED, HIGH PRECISION bearing applications**

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KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE NO. 31 ON INQUIRY CARD

RUGGED

Elapsed Time Indicators

BY ELGIN MICRONICS

This unusual photograph (taken just before Bernard Butterfingers left our shipping room) shows an Elgin Micronics ETI passing the old random sample bounce test. We test against MIL-M-26550 now and surpass the shock and vibration requirements very easily. After all, a 20G, 11ms shock is just a love pat compared to an umpteen G bounce. You'll find Elgin Micronics ETI's surprisingly small and light too, despite their rugged construction—just right for aircraft and missile equipment. Digital or dial read-out models, AC or DC, are available. Write today for specs—ask for bulletin ETI-1.

ELGIN MICRONICS

DIVISION OF ELGIN NATIONAL WATCH COMPANY 366 Bluff City Blvd., Elgin, Illinois

Plants in Elgin and Rolling Meadows, Illinois and Chatsworth, California

Represented nationally by Airsupply-Aero Engineering Company, a division of The Garrett Corporation

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COMPONENTS DIGEST

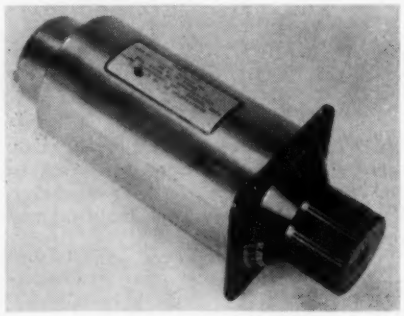


Fig 11 Settable interval timer by Globe Industries. Package is 2.265" diameter by 6.205" long and weighs less than 2 lbs.

vdc, 0.075 ampere-peak from 5 ohm impedance power supply; and radio interference, Mil-1-26600. Digital readout gives 1,000 hours in 0.1 hour increments or 10,000 hours in 1 hour increments.

Globe Industries

Globe places their emphasis on military timers; all of their units are custom designed to customers' specs and performance requirements. One of their basic types is a settable interval timer which is standard for the LABS (Low Altitude Bombing System) program and provides settings from 0 to 30.0 seconds in 0.2 or 0.1 second increments, by hand turning of a detented knob, with or without digital readout. The LABS timer, shown in Fig 11, operates on 28 vdc and provides accuracy of ±1% of the set interval, or 0.1 second, whichever is greater. The unusual feature of this timer is the fact that it uses a 7/8" diameter motor driving through a mechanical escapement with a drive accuracy of better than ±0.5%. The timer switches handle 5 amp. resistive loads.

For applications in which only dc power is available, Globe has an electronically governed timer which uses a dc synchronous motor system developed by Globe. Timing accuracies of ±0.01% or better are achieved. The electronic motor control package alone is 5" cubed and weighs a maximum of 5 ounces. It may be applied in timers in conjunction with any Globe dc permanent magnet motor.

Globe also makes ac and dc timers for many functions. AC timers are limited in accuracy only by the control frequency accuracy. Mechanically governed dc timers are routinely within ±3% accuracy. Both types can in-

clude a number of switching and follow-up functions to individual requirements. Globe Industries is located in Dayton, Ohio.

A. W. Haydon

Miniature, hermetically sealed repeat cycle timers, by A. W. Haydon, Waterbury, Conn. consist essentially of a motor turning a cam shaft which actuates one or more switches in a predetermined sequence and repeats continuously. Where only one cycle is required per operation, the motor can be wired through one of the switches, and thus stopped at the end of the cycle.

Timing accuracy involves two factors: the cycling time of the cam shaft and individual cutting and setting of the cams. Cycling time accuracy is dependent on the motor only and can be influenced by choice of motor based upon voltage (and frequency) range and other factors such as ambient temperature range which might cause speed variation.

Standard dc motors are normally specified where cycling times within ±10% at rated voltage and temperature are required. Governed dc motors

Fig 12 A. W. Haydon's motor driven time delay relay. Accurate timing with precision timing motor in conjunction with stepless clutch drive which reduces errors to an extremely low value.

are used where cycling time must be held within ±0.1% over wide voltage variations. AC units are specified where power is available to operate synchronous motors. This, of course, has the advantage of providing an accuracy dependent only upon the regulation of the line frequency.

The accuracy with which cams can be cut and set for a given sequence depends to a great degree upon the number of cams involved, but is nominally specified as ±6° angular for the setting of each drop in the cam. This angular tolerance can be converted into terms of time and this, together with the tolerance on cycling time, will set up the timing tolerance for the unit.

Up to 10 switches can be incorporated into A. W. Haydon's repeat cycle timers. Inter-cam-shaft reductions can be provided to allow several cam shaft speeds. One way ratchet drives are installed in the dc motors to

SHOWN 1½ NORMAL SIZE

0.1% LINEAR OUTPUT OVER TEMPERATURE RANGE

SIZE 11 DC TACHOMETERS

These Kearfott DC tachometers are unusually durable and specifically designed to provide reliable service over a long life. R9608-001 is an uncompensated unit ideally suited to function as a stabilizing element in a standard DC servomechanism. The R9608-002 model offers the precision required in computing applications and is temperature compensated to maintain its high accuracy over the temperature range of −15°C to +71°C, with variations of no more than .1% of values specified at 25°C.

		R9608-001	R9608-002
TYPICAL ELECTRICAL DATA	Output (volts/1000 rpm)	7 (typical) .5-30 available	2
	Rated Speed (rpm)	3600	5000
	Linearity (% to 3600 rpm)	.07	.1
	Winding Resistance (ohms)	125	
	Output Impedance (ohms)	—	36
	Ripple Voltage	2% above 100 rpm	2.5% at 3600 rpm
TYPICAL MECHANICAL DATA	Friction Torque (in. oz.)	0.25	0.25
	Rotor Moment of Inertia (gm-cm²)	7	8
	Weight (oz.)	5.5	5

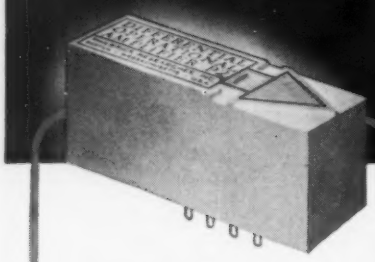
Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE NO. 33 ON INQUIRY CARD

The all-new, all solid-state Philbrick P2 amplifier



NO TUBES, NO CHOPPERS, NOTHING BUT PERFORMANCE. An ingenious arrangement of all solid-state components endows this operational amplifier with the most remarkable and versatile characteristics. But let's let them speak for themselves. *Full differential input:* truly floating with respect to ground. *No common mode error. Low input current:* typically 10^{-11} amps. *Low noise:* typically under 10 microvolts in the dc to 1 kc range. *Sub millivolt long term stability:* less than 100 microvolts drift per day. *Cool running:* typically 330 milliwatt dissipation. *Wide band pass:* typically 75 kc as a unity gain follower. *High open loop gain:* typically 30,000. *Truly low cost:* **$210.**

Use the P2 for instrumentation, analog computation, and other applications requiring high reliability and accuracy. Discover its marvelous versatility and convenience. Add, integrate, scale, invert with it. Take advantage of its differential inputs to perform very high impedance voltage following (or amplification), precise current driving, and many other useful applications. The P2's output delivers 1 ma at ±10 volts. The cast aluminum housing fits right in your hand.

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COMPONENTS DIGEST

prevent damage to the timer in case polarity of the power supply is inadvertently reversed. Standard units operate under vibration of 5-55 cps at 10g max. acceleration.

A. W. Haydon sub-miniature repeat cycle timers are approx. ¼ the size of the standard units and weigh ½ as much. Basic weight with one switch is 6½ oz. and overall length is 2 11/16 inches.

Shown in Fig 12 is A. W. Haydon's special motor-driven time delay relay enclosed in a 2.2" diameter aluminum housing. Originally designed for a specific military application, these units are now available for other uses. This miniaturized unit is provided with a large adjusting knob to facilitate changing of the time setting. The time delay period can be readily adjusted in fine increments over the range. A positive detent arrangement maintains the time setting under all conditions of operation. Rugged construction assures operation under severe conditions of vibration, shock and sustained acceleration.

Although not hermetically sealed, the design of the unit provides protection from adverse environmental conditions. Accurate timing is assured by use of the company's precision timing motors, in conjunction with stepless clutch drives, which reduce clutch errors to an extremely low value, allowing accuracies to be maintained as specified over the calibrated range of adjustment. Specifications include: Mil-E-5272C; Mil-1-6181B for radio interference filtering; accuracy over calibrated range of adjustment (24-29 volts dc, or at 60 or 400 cps), ±0.1 second or ±1% of the setting, whichever is greater, over the temperature range – 54°C to 71°C, or rated life; weight is twenty-two ounces for dc and 400 cps units, or eighteen ounces for 60 cps units.

A. W. Haydon also makes interval timers, elapsed time indicators and custom designed timers.

Haydon Div., General Time

Designed on a modular concept, an external clutch reset "Acrotimer", by Haydon Div., General Time Corp., Torrington, Conn., meets a very wide range of physical and electrical requirements at a minimum expense. The unit, employing a motor, solenoid, an external clutch and a variety of load and relay switches, acts as a delay or interval timer and opens and

New Philbrick 6033 solid-state power supply

BALANCED OUTPUTS, COMPUTING GRADE. The 6033 is the latest addition in the distinguished line of Philbrick power supplies. It will energize at least 10 Philbrick P2 amplifiers and other transistorized electronic equipment. Like the P2, its remarkable characteristics speak for themselves. *Low internal impedance:* less than 2 milliohms. *Low noise and hum:* guaranteed less than 150 microvolts rms (0.001%). *Highly regulated outputs:* against load, less than 300 microvolts; against line, less than 200 microvolts. *Low long term drift:* typically 0.1%. *Short transient recovery time:* no load to full load, less than 1 millisecond. *Unique short circuit overload protection:* inherent in the 6033's design with no extra circuitry to deteriorate performance. *Truly low cost:* about half that of supplies with comparable performance: **$285.**

Operates from 115 volt, 50–400 cycles, providing up to 150 ma at plus AND minus 15 volts, slaved to a common reference. Conveniently packaged, cool running, and highly reliable. Available as bench model or modular plug-in. Bench model dimensions: 3½" h x 5½" w x 7½" d. Also available with 300 ma output.

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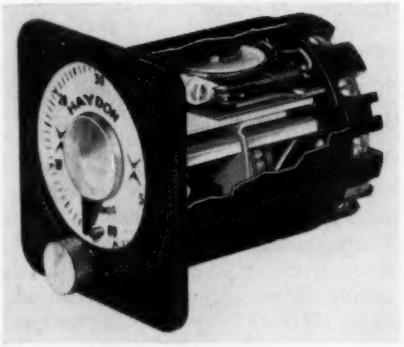


Fig 13 Haydon Div., of General Time Corp., makes an external clutch reset timer, called Acrotimer, which is constructed on the modular concept. Twelve variations meet many timing requirements.

closes switches during and after a preset interval.

The timer, (Fig 13) can be actuated either manually or automatically by sustained or momentary contact. It can also be initiated by the closing of a relay, either external or kicked off by another timer.

Actuation starts the motor and engages the clutch. A trip arm driven by the motor trips one or two SPDT load switches. This will de-energize the motor, open or close a load, and, if wired, release the clutch for automatic reset. Spring-type clutch insures positive engagement with less wear and longer life.

Time ranges are 6, 15, 30, 60 and 120 seconds; 5, 10, 15 and 30 minutes and 1, 2, 4, 8, 16, and 24 hours. Accuracy of repeatability is 0.5%. Unit is guaranteed for operation from 0 to 55°C.

Haydon Instrument Co.

A new concept in mechanical transfer of numbers by a planetary gear drive has been applied in Haydon Instr. Co.'s PlanetGear Clocks which are precision built for long, heavy-duty, split-second timing. Instantaneous snap-over of numbers is accomplished by a nylon cam and roller compensating device (illustrated in Fig 14), which moves the "always-in-mesh" planetary gear. This means all digits are in full view at the read line at all times.

Since the torque required to drive these digital clocks is uniformly low, miniature timing motors in various voltages and frequencies are used. Preset of hours and minutes is manual. The set knob on the side is geared to the seconds drum with a step-up ratio of 8 to 1. Numerals are ⅜" high to MS-33558 (ASG). 24 and 12 hour clocks are available in the same package size with the same ⅜" high numeral markings of 1 to 24. The company is in Waterbury, Conn.

SETTING THE PACE

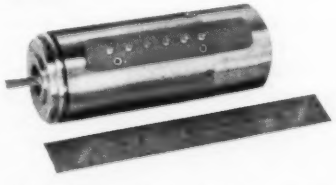
by Eston Fox, Sales Manager, Pace Controls Corp.

New Key Component for Servo Control

Modern high precision servomechanism control systems are now benefiting from a revolutionary new concept . . . the DIGITORK Incremental Motor. Unique among "stepping" motors, this *true* motor provides high speed, torque, accuracy, and repeatability while eliminating many design problems encountered in systems using conventional servos. Available with torques up to 20 in.-lbs. (higher with "specials") and controlled stepping rates up to 3000 per second, it's the *logical* motor for use with today's advanced digital techniques.

Inherent High Accuracy

The DIGITORK motor is a true digital motor. It responds with a discrete increment of motion to each signal pulse. Speed of motion is controlled by the rate of signal input. An increment can be made any integer or fraction, with the whole motion equal to the sum of the equal increments. Any motor error zeroes out at every third step. Thus the maximum error of the whole motion can be no greater than the error inherent in one increment. This high precision design also eliminates the hunting and instability common with conventional servos.



Model M118 DIGITORK Motor provides 0-2800 steps per second and 2 oz.-ins. torque.

Simplicity and Economy

The DIGITORK motor as a control component, with today's digital trend in circuit design, is far more compatible than conventional servos. Using it, performance of other components and sub-systems can be more easily predicted. The DIGITORK motor usually eliminates the need for such elements as highly complex amplifiers, tachometers, transducers, and analog-to-digital convertors, thus cutting system costs considerably.

"Servo" vs Digitork

Let's consider a hypothetical problem; control of two linear motions . . . 1 inch and 100 inches respectively. Handled by a conventional servo, total length in each case is treated as an entirety from one bit of information. Any error in the bit will be reflected in the accuracy of the total motion. Since the servo utilizes feedback for positioning, this introduces errors inherent in the circuit and tolerances in the overall length, including those produced by overshoot and backlash. And since the total percentage error is the same for both controlled motions, actual error for the 100-inch motion may well be greater than the whole 1-inch motion! This error can be reduced by the addition of more components, circuitry and cost, but – this is not necessary when using DIGITORK – as described below.

Using a DIGITORK motor for the same two motions, control of total length motion is achieved through a finite number of equal incremental motions. Accuracy of the whole depends on that of just *one* increment, regardless of the total number. Thus, we can use a DIGITORK motor with each step equal to .001" linear motion ... rated error for one step being ±.0001". So, 1000 signal pulses will advance it 1000 steps (1 inch) and 100,000 pulses will advance it 100,000 steps (100 inches). Total error in each case: ±.0001 inches.

Digitork Motor Applications

The DIGITORK motor is presently in use in systems requiring accuracies of .000020" linear and .002 degrees rotational. It can be used to precisely coordinate and control motion between two or more axes. Size of resultant motion can be changed by appropriate gearing.

Put this accuracy and versatility to work on your control problems. Write for Engineering Bulletins today.

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COMPONENTS DIGEST

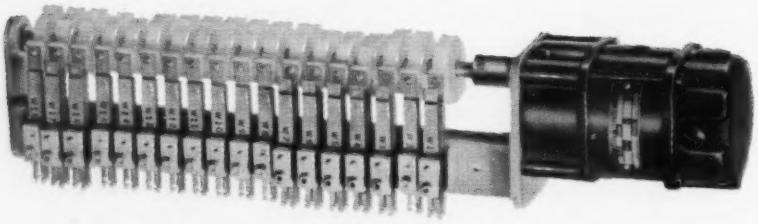


Fig 15 Motor-driven interrupter by Holtzer-Cabot consists of an instrument gearhead motor, nylon cams and a maximum of 18 spring packs.

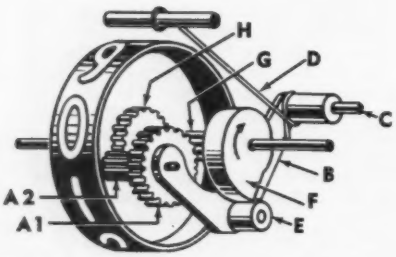


Fig 14 Instantaneous snap-over of numbers is accomplished in Haydon Instr. Co.'s digital clocks by a smooth planetary rolling gear action. Planetary wheel and pinion assembly "A_1" and "A_2" is moved by arm "B" pivoting on shaft "C". Spring "D" holds roller "E" against cam "F". Cam "F" and pinion "G" are molded as an integral part of the next lower order drum not shown. Gear "H" is molded as part of the drum shown. Gears "G", "A_1", "A_2" and "H" have a total ratio of 10:1 so that each adjacent drum rotates one tenth as fast as the preceding drum. However, as the lower order drum rotates from 0 to 9, Cam "F" moves the planetary assembly "A_1" and "A_2" down to prevent motion of the drum shown. When the lower order drum rotates from 9 to 0, the roller "E" rides up the steep slope of cam "F", thereby returning the planetary wheel and pinion assembly "A_1" and "A_2" to its original position, causing quick transfer of the number on the drum shown.

Holtzer-Cabot

Equipped with precision cut nylon cams, Holtzer-Cabot's motor driven interrupter units provide extremely accurate timing and long life. Either ac or dc drive from an instrument type gearhead motor is available. Model 25BC18, shown in Fig 15, contains a maximum of 18 spring packs each of which may contain a maximum of 6 springs or leaves. Shaft speeds range from ½ to 12 rpm. Holtzer-Cabot is a div. of National Pneumatic and is located in Boston, Mass.

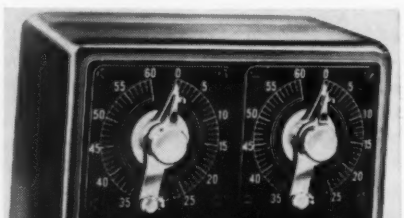


Fig 16 In Industrial Timer's Series Dual-Trol recycling timer, timing modules are housed in a sturdy two-piece baked enamel steel housing, which can be back-mounted to a machine tool or control panel. Timer operates on either 115 or 230 volts at 50 or 60 cycles. The SPDT switch is isolated electrically from the timer motor circuits, and is rated at 10 amps, non-inductive at 115 volts and 60 cycles. Compact unit measures only 7½" X 5⅛" X 5 9/16". Unit is priced at $77.50, which includes the housing and any two timing modules. Additional timing modules are priced at $27.50.

Houston Fearless

Subminiature elapsed time indicators from Houston Fearless Corp., L. A., Calif., are low power dc precision instruments for military applications. Easy to read dial records total hours of a circuit's operation. Standard ranges are 1000 to 10,000 hours. Specifications include: weight, 2 oz max.; voltage, 20 to 30 vdc; power draw, 1.5 watts approx.; altitude, 100,000 feet; operating temperature, −65 to +160°F; accuracy, 1%; meets or exceeds applicable portions of Mil-E-5272C.

Industrial Timer

A highly versatile recycling timer called the Series Dual-Trol is what Industrial Timer Corp., Newark, N.J., believes to be the smallest recycling timer available with interchangeable timing elements. The timer is ideally suited for control of machine tools, material handling and chemical processes or virtually any operation where "on" and "off" intervals must be frequently changed. Unit is shown in Fig 16.

The time interval of both the "on" and "off" signals is easily changed by adjusting the timing knobs on the face of the two timing modules. One module controls the duration of the "on" cycle; the other controls the duration of the "off" cycle. With any two timing modules, the duration of either the "on" or "off" interval can be adjusted within a wide range. For example, with 3-hour and 30-minute modules, a 30-minute pulse can be produced every 3 hours. However, both modules can be adjusted within a wide range to produce other time intervals. For example, the 30-minute

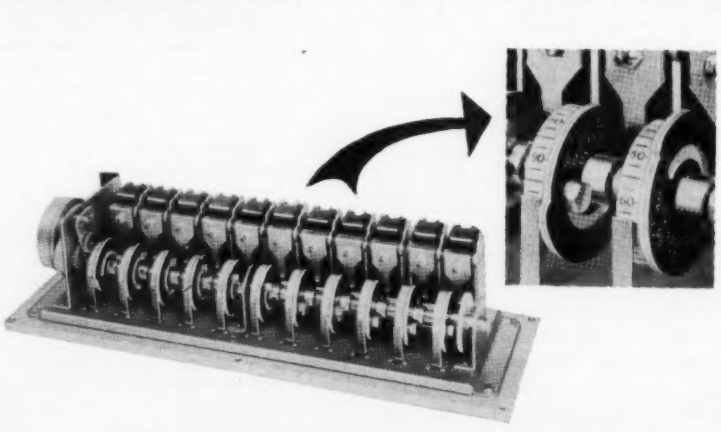


Fig 17 Industrial Timer's Series MC Multi Cam Timer controls from 2 to 20 circuits. Cams mounted on a single driving shaft are coupled to motor by gear and rack assembly. Each cam is independently adjustable for 2% to 98% of the total time cycle. Individual adjustability enables the unit to be used as a programming device. Any combination of timed sequences can be used. Enclosed SPDT switches are mounted on individual brackets permitting removal without disassembling entire switch bank. Contacts are rated at 10 amps non-inductive ac.

module can be adjusted between 30 minutes and 30 seconds, in 30-second steps. Modules can be replaced simply by removing four screws. A total of 10 timing modules is available with the Series Dual-Trol unit, with maximum time ranges extending from six seconds to three hours.

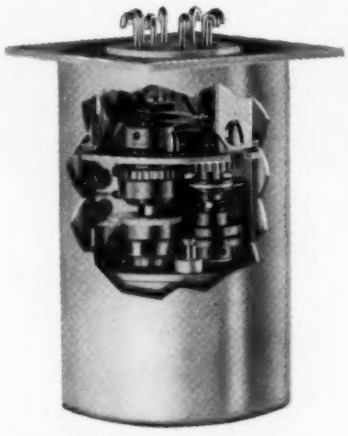


Fig 18 Industrial Timer's hermetically sealed Series F recycling timer. Voltage ranges from 6 to 230 at 25 to 400 cycles. Chronometrically governed dc motors are available for applications requiring extreme accuracy using dc current.

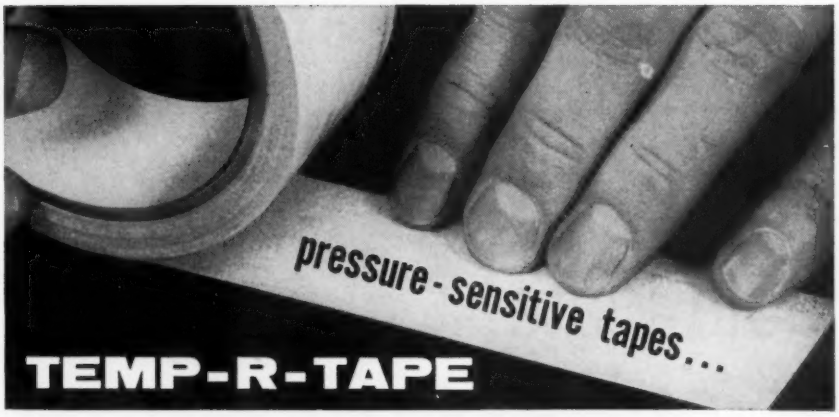
Industrial Timer's hermetically sealed timing units for military applications include a recycling timer, a time delay unit and a running time meter. The recycling unit, shown in Fig 18, continuously recycles 1 to 7 cams which actuate SPDT load switches in a preset ON-OFF sequence.

The company also makes a series of cam cycle timers with 50 standard ratio gear and rack assemblies stacked for changing overall time cycles. A multi-cam unit of this series is shown in Fig 17. They also make synchronous motor driven time delays, interval timers, signalling timers and reset time totalizers.

A useful item from Industrial Timer is their Multi-Cam Timer Kit – a basic construction kit for experimental work. It consists of all parts required to assemble four multi-cam timers. Complete tools and necessary hardware are included.

Lake City, Inc.

Small, compact general purpose timers from Lake City, Inc., Subs. of Controls Co. of America, Crystal Lake, Ill., contain a direct motor drive with no coasting or sub-synchronous operation. As shown in Fig 19, Model VC 200 has a snap switch which is rated for 20 amp heavy duty. Special lubrication available for extreme ambient conditions: +150° to −15°F with im-



for −100° F to 500° F applications

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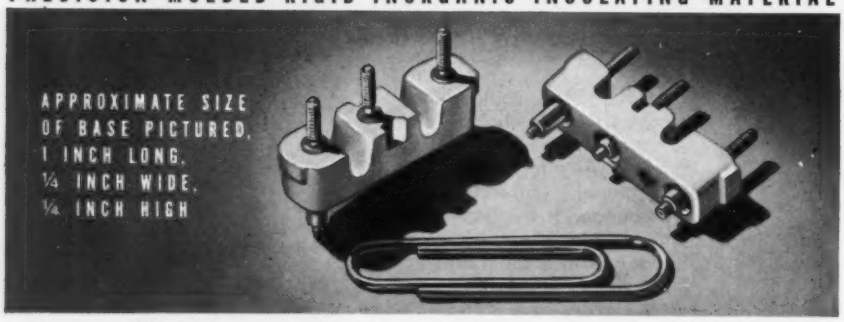

This miniature switch base molded with Havelex, contains four different stainless steel inserts with precious metal plating. Three inserts (which include #0-80 male threads) go all the way through the mold and provide precision mountings on both sides for assembly. The #0-80 female threaded insert is designed to protrude from one face and is approached by a molded counterbore from the other. Mold is designed to accommodate alternate terminal inserts when unthreaded models are required.

Haveg engineers recommended Havelex for this particular molding because of its combination of properties. Completely inorganic, with metal inserts integrally molded in place. Precision tolerances with faithful reproduction from part to part. Heat resistance for continuous operation in excess of 700°F.

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COMPONENTS DIGEST

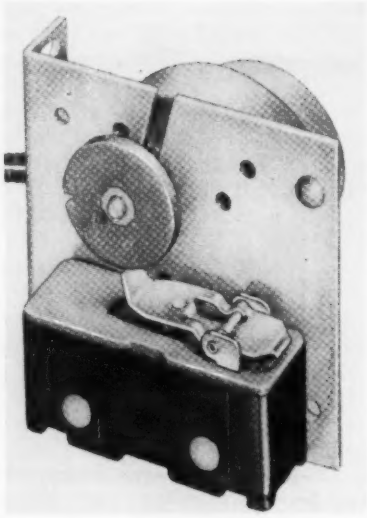

Fig 19 General purpose timer by Lake City Inc. features a direct motor drive giving a small compact flexible design.

mediate starting. Standard speeds range from 1/60 to 10 rpm.

Molon Motor & Coil

For low accuracy applications, Molon Motor & Coil Corp., Rolling Meadows, Ill., has a general purpose cam assembly driven by a shaded pole motor (non-synchronous). Gear trains drive a total of seven adjustable cams for actuating leaf type or snap action switches. Cams can shut unit off, or develop repeat cycles or what have you. Speed varies from 1/5 to 800 rpm.

Sangamo Electric

For power line control application, Sangamo Electric Co., Springfield, Ill., makes a complete line of motor-driven time switches. A typical unit is Type WY which handles two circuits with a carryover feature that protects against loss of timing due to power failure. If power fails, a timing escapement is released allowing the dial to be driven by a mainspring for periods up to 10 hours. When power is restored the escapement is blocked, the mainspring is automatically rewound and the synchronous motor again drives the dial. Minimum ON period is 30 minutes; minimum OFF period is 2½ hrs. When specified, these time limits can be reversed.

Spectrol Electronics

Preset sequence timers or function

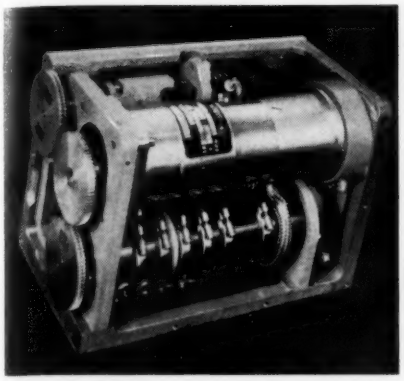

Fig 20 Spectrol Electronics' function programmer is used to control the attitude of a missile with respect to time. It consists of a governed dc motor, a potentiometer, and five dry circuit switches. It also contains a mechanism which stops the unit at the end of its timing program of 120 seconds and allows resetting in one-half this time.

programmers are manufactured by Spectrol Electronics Corp., San Gabriel, California. Construction of the switch section consists of a machined pyrex glass base with precious metal switching sections cemented in machined grooves around the diameter of the glass base. A rotating wiper contacts the various segments around the diameter to complete the timing circuits. Speed of rotation of the wiper and the spacing and length of the metal switching sections determine the timing sequence.

There are several advantages to the glass backed switch type of construction. Since the grooves in the glass base are machined, the spacing between timing sections can be held to very close (± 6 minutes of arc) tolerances. The glass and precious metal switching section is lapped and polished to extreme smoothness (4 microinches). In addition, the glass has good hardness and low coefficient of friction (low torque) and low thermal expansion (dimensional stability). The glass also has excellent insulation resistance and dielectric properties.

Line power requirements for the timers are basically constant dc voltages or constant frequency ac voltages. When the line voltage or frequency fluctuations are too great for accurate timing an internal power supply is used to regulate the voltage or frequency to the required accuracy.

Spectrol's timers can be made to reset in several different ways. The first is completely automatic, whereby the timer is started, goes through its timing cycle, then stops at its initial position ready to start another cycle. The second reset type is the case in which the timer goes through a cycle and stops at the end of the cycle. After this, a voltage is applied to the timer to reset it. Or, a manual reset knob can be turned to reset the timer.

To facilitate the first two methods, units have been built with an extra switch section to actuate an electromagnetic clutch. Similarly, relays, spring returns and detents are regularly used to provide special reset mechanisms. Typical function programmer is shown in Fig 20.

The gear ratio and switch segment placement around the diameter can be varied to give any desired time delay from 5 seconds to 10 hours. Time delay is factory adjustable to ½% of the total time delay and is repeatable within ¼% of the total time delay. Smooth finish and high hardness of the switch section gives a long life (in excess of 1,000,000 cycles). Typical size is 2″ x 2″ x 4″ and typical environmental conditions include: temp., −65° to +250°F; vibration, 20 g to 2000 cps; acceleration, 30g. The main use for these timers has been in missile applications; however, they apply to many industrial automation and control devices.

Standard Electric Time

Precision electric timers for accu-

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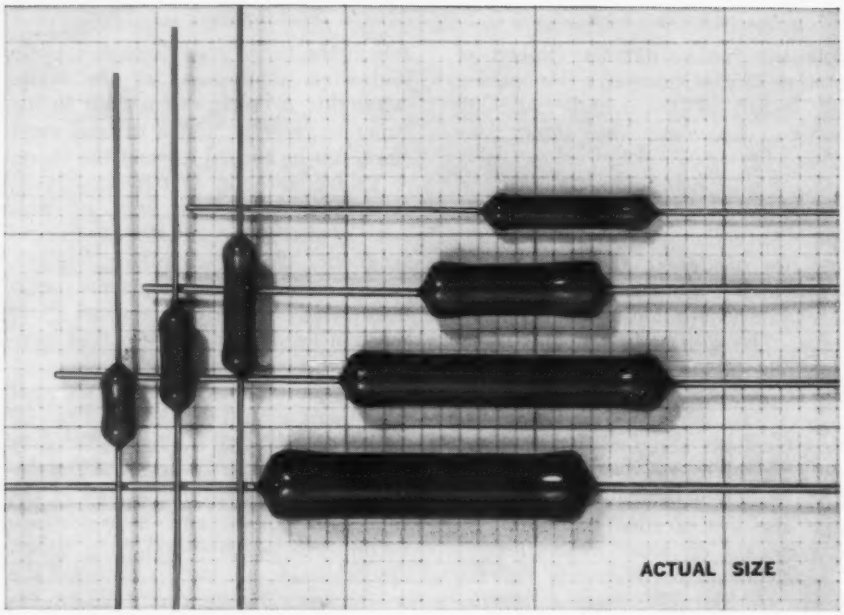

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SIZES AND RATINGS

Rating (in watts)	Type	Resistances (ohms)		Dimensions (inches)	
		Min.	Max.	Length*	Diam.
2	2X	0.1	5,000	3/8	3/16
3	3X	0.1	10,000	1/2	3/16
4	4X	0.1	15,000	11/16	3/16
5	5XM	0.1	20,000	15/16	3/16
7	7X	0.1	25,000	1	3/16
10	10XM	0.1	50,000	1 3/4	5/16
12.5	12.5X	0.1	75,000	1 3/4	3/8

*Less leads.

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COMPONENTS DIGEST

rately measuring elapsed time, from Standard Electric Time Co., Springfield, Mass., are used in laboratory, testing, and production work in industrial and commercial plants, governmental agencies and educational institutions. Many different models with various types of mountings such as panel and wall types are available. All Standard's timers are driven by synchronous motors regularly furnished for 115 v ac, 60 cycle operation; other voltages and frequencies are optional.

Where clutch is to be operated from an electronic circuit it can be connected directly in the plate circuit of any one of several types of tubes. Characteristics of this clutch are: voltage, 120 dc; resistance, 2000 ohms; current, 50 to 60 milliamperes.

Standard Electric's models have a manual resetting lever at the upper left hand corner of the timer. An electric solenoid resetting mechanism, remotely controlled, is optional. Each type resets both hands to zero instantaneously, and may be operated without harm even when the hands are running.

Fig 21 Waltham Precision Instrument Co.'s subminiature elapsed time indicator. Jewel bearings in unit have less friction loss even at extreme temperatures.

Waltham Precision Instrument

Light and reliable with jewel bearings, Waltham Precision Instr. Co.'s subminiature elapsed time indicators give digital readout to 9,999 hours. Total weight is 3-3/4 oz. and outside diameter is 1-1/16". Unit, shown in Fig 21, is 2-11/16" long. Maximum power input is 2-1/2 watts. Small cumulative error when used in "on-off" operation, the motor reaches synchronous speed virtually the instant power is applied. Unit is hermetically sealed in accordance with military requirements – Mil-E-5272B.

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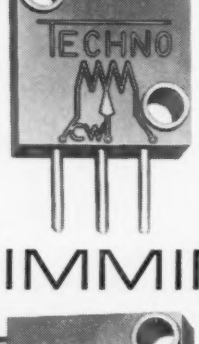

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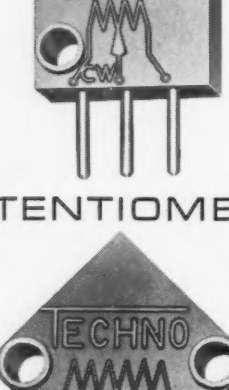
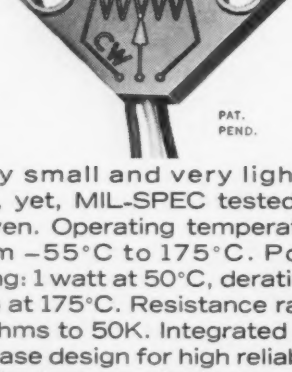


POTENTIOMETER



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COMPONENTS DIGEST

Western Design & Electronics

An extremely accurate, fixed position timing device, a precision interval timer made by Western Design & Electronics, Goleta, Calif., has up to five independent channels available in the standard unit; events may be sequenced simultaneously or in series, or in a combination of both. On special order, the number of channels may be increased to 10 as the synchronous motor has ample torque to handle the increased operating load.

In addition to the synchronous motor, the unit consists of a unique cam and positive action contact arrangement in which one set of contacts makes and the other set breaks the circuit. This action sharply defines the start or finish of any pulse and is accomplished by the use of abrupt discontinuities on the cam surfaces which permit the tripping points to be set precisely. Speed of contact operation is independent of the speed of rotation of the cams.

Total contact bounce on the circuit make and break is so slight it can be measured in microseconds, less than 300 microseconds on make, and less than 50 microseconds on break, in production line units. Tolerance of the timing pulses is held to ±1/5 of one percent or ±10 milliseconds, whichever is greater. These tolerances are relative to a 60 cycle or 400 cycle time base accuracy. Timer will run repeatedly through a pre-set timing cycle which may be as short as one second or as long as several hours.

Zenith Electric

Model WL multi-circuit cycle timer by Zenith Electric Co., Chicago, Ill., is especially adapted for applications in enclosed equipment where pilot circuit control is required. As shown in Fig 22, each SPDT open-type, snap-action switch is mounted individually and can be removed without disturbing any other. Switches are operated by adjustable cams driven by a synchronous motor. Unit operates in a repeating sequence or continous cycle; or operates one cycle only and stops when control is actuated by a momentary contact pushbutton. It can also be used as as interval timer for manual start and automatic stop.

Zenith also makes interval timers, elapsed time indicators, automatic reset and percentage timers. Shown in Fig 23 is their Model 3406R indexing interval timer. • • •

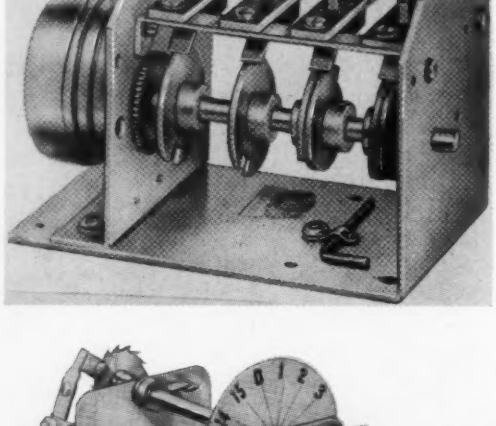

Fig 22 Multi-circuit cycle timer of Zenith Electric is available with 2 to 7 circuits. Switch capacity is 5 amps, 110 volts ac, non-inductive.

Fig 23 Zenith Electric's 0-30 minute indexing interval timer. Indexing is accomplished with a numbered counting dial. As many as 15 separate steps are automatically registered on the counting dial each time the unit is set for the next part of the cycle. Either manual or electrical reset can be supplied.

COMPONENTS DIGEST 13

Magnetic Clutches & Brakes Part 2

Industrial Units

In our Components Digest on magnetic clutches and brakes, we considered, mainly, the important factors involved in selecting units for military applications such as precision servomechanisms. The increased use of data processing equipment provides another large area where high response friction clutches are used to great advantage. A typical example is the indexing and feeding of paper in high speed printers. As a supplement to the Digest coverage, we present here a report from Simplatrol Prods. Corp., Worcester, Mass. which discusses a number of considerations important to the use of clutch-brake units for these industrial applications.

First, the unit must accelerate the load to the required rpm and stop it within the time specified. It must be rugged enough to withstand constant operation of hundreds of cycles per minute in many cases, without failure or excessive wear. Secondly, the clutch-brake itself many times must do the indexing, meaning its repetitive accuracy must be within well defined limits. In the case of paper feed for high speed printers, the clutch feeds and the brake stops and positions the paper every cycle without benefit of any mechanical stops. In a card puncher and printer, the brake will have to position the card so that the printing will come between the rows of punched holes. Since the clutch-brake is a friction device, accurate repetition is many times the qualifying feature between competitive types. Thirdly, because the equipment employing the clutch brake may be located where noise level is important, as in the case of data processing equipment, smoothness and quietness of operation is a major selection factor.

THROUGH SHAFT OR COUPLING

Confusion often arises over the difference between a through shaft clutch and a coupling clutch. Clutch coupling engages or disengages two shafts in line, while a through shaft clutch transmits drive from a parallel shaft to the shaft on which the clutch is mounted, the shaft passing through the unit.

In clutch coupling, one member of the clutch contains bearings and idles on the shaft, in the de-energized state, while the other clutch member is fastened to the shaft; when the coil is energized the drive is transmitted from the idling member to the shaft, locking them together. While the coupling presents a straight-forward approach to joining two elements, it also presents the major problem of alignment between the input and the output shafts. If they are not carefully aligned, loss of clutch torque and excessive heating and wear may occur. Because the coupling members are cantilevered on the shaft ends, adequate bearing support must be provided.

In a through shaft clutch, alignment and clearance between the clutch members are automatically established and it is properly supported by bearings on each end. Because of the inherent advantages of the through shaft type, they are recommended whenever possible, and especially for high cycle rate applications. It is generally easier to install, much easier to service in the field, and more rugged.

ROTARY OR FIXED FIELD

In a rotary field type, the coil member is one of the clutching elements and is fed through slip rings and brushes. A fixed field has a stationary magnet, necessitating the introduction of a third member, called the rotor, between it and the armature. The rotor transfers the magnetic flux from the magnet to the armature and the clutching action takes place between the rotor and armature. Bearings are used between the stationary magnet and the rotor to maintain correct spacing.

Fixed field types eliminate the need for brushes and in certain cases must be used because of environmental conditions, or where there is not sufficient room to mount brushes. However, there are a number of disadvantages when comparing them to the rotary field clutch. First, the fixed field clutch is inherently less efficient because of the fixed air gap which is necessary between the stationary coil member and the rotor; which means additional ampere turns must be provided to maintain the required flux to produce an equivalent torque rating. This means extra turns or additional current draw. Secondly, because the air gap between the magnet and rotor must be kept at a short distance and between close limits, the extra ma-

TABLE I

SELECTION FACTORS

Characteristics that affect high response and repeatability in clutch brake combinations:

1. Armature transfer distance between clutch and brake housings.
2. Parallelism between engaging surfaces.
3. Backlash between armature and shaft.
4. Well mated-in friction surfaces.
5. Tolerances and finishes on all important surfaces.
6. Armature inertia and mechanical strength.
7. Suitability of clutch brake (governed by its magnetic characteristics) to respond to forcing type electrical circuits.
8. Residual magnetism effects.
9. Operating noise.
10. Smoothness of operation.

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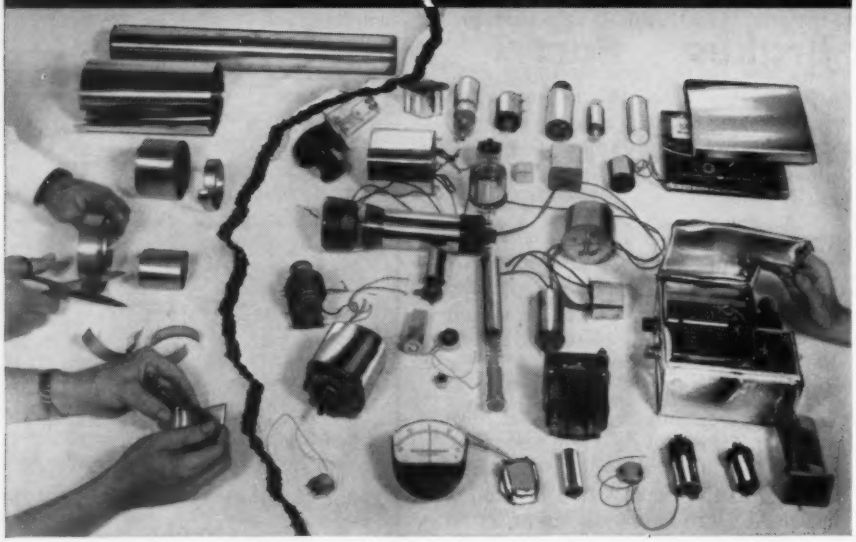

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COMPONENTS DIGEST

chining required results in a higher priced item. Lastly, because of the mechanics involved, the fixed field unit is not as readily adaptable to special configurations and mountings, especially in clutch-brake or duplex clutch combinations.

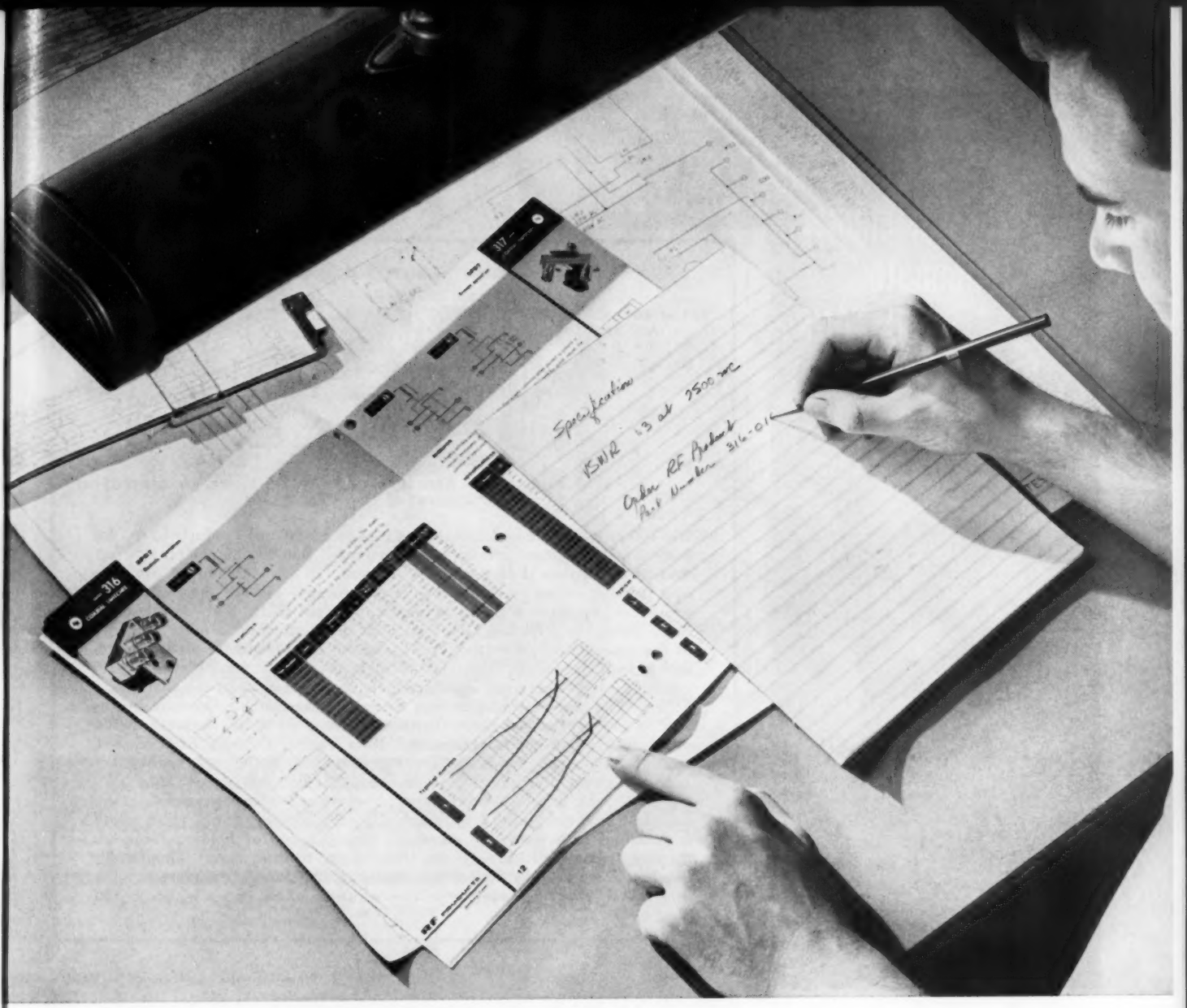
Chief drawback to the rotary field type is the use of brushes. While it is true that there is a wear factor involved on the brushes this can be kept to a minimum by proper design of slip ring and brush material, the type of brushholder, and proper installation. It should be pointed out that if solid collector rings are used and very low currents are involved, duty is not comparable to that of commutation in a dc motor or a generator. Indeed, if designers remember the timers, slip ring assemblies for antennas, or other applications where slip rings are used as a matter of course they might not be as concerned in applying rotating field clutches, even in military equipment. And while it is true that brushes do wear, this can be readily observed, and replacement under periodic maintenance procedures is extremely simple. Also the brush wear has to be weighed against the life of the bearings used between the field member and rotor of the fixed field type.

Another objection raised to the rotating field type is the high inertia of the coil member, but in many cases this is a decided advantage because if this is the constantly idled half of the clutch, it introduces a flywheel effect which is transmitted to the load to be accelerated. Of course this is true only if the manufacturer has designed this clutch so that the magnet member will be the constantly idled half.

In summation then, either a fixed field or a rotary field type may often be used in a particular application, but the designer of a high response system should consider the rugged, simple construction, and the ease of application of a rotary field clutch before arbitrarily rejecting it.

LOCATION IN SYSTEM

Usually in a high cycling application where indexing accuracy is required, the clutch-brake will be on the output shaft itself, directly controlling the load. This avoids any lost motion in gears, pulleys, or belts between the prime mover and the output shaft, as well as eliminating the energy that would be required to accelerate



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It's easy. DK Coaxial switches are available in scores of shapes, sizes, and functions *from factory stock.* RF Products' new DK Coaxial switch catalog lists over 130 variations of 16 basic coax switch designs, covering a proven 90% of all known applications. All the facts and figures on the industry's most complete line of coaxial switches are at your finger tips.

You'll also find that these switches successfully combine ruggedness with the highest standards of precision: spring-leaf switching blades, gold-plated silver contacts and impedance matched connectors keep insertion loss and VSWR (1.3 @ 4,000 MCs) low, Crosstalk high (in decibels down); electro-mechanically actuated models operate and release in 8 to 20 milliseconds, depending on type and function, with a proven mechanical life of 1,000,000 cycles minimum when operated under 10 cps.

And, don't forget that RF Products, pioneers in the development of the coaxial switch, will continue to offer you design and engineering services whenever you need them. Whether you order a switch from the catalog or a switch designed to meet your exact specifications, you can be assured of the same high quality and service.

For details on our new line of standard switches, write for catalog DK 61.

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CIRCLE NO. 68 ON INQUIRY CARD

MULtiLAYER*

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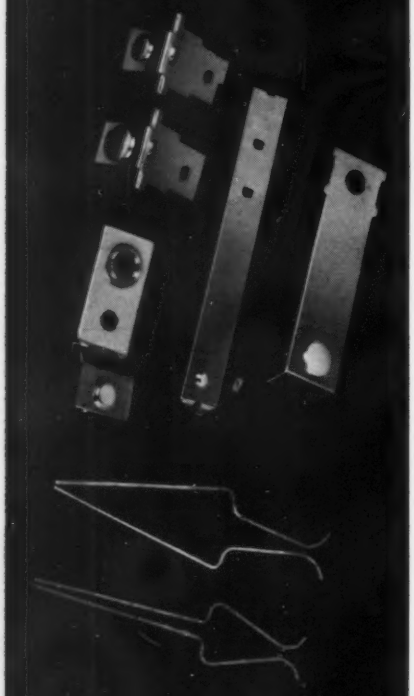

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Take a strip of spring steel, clad an overlay of copper to it, weld and coin a precious metal ball at the exact contact point. The result . . . a MULtiLAYER relay part with operating qualities impossible to obtain through the use of any single alloy or plated material. When blanked and cut off, this part gives you maximum reliability, peak performance without compromise, occupies a minimum of space and costs a fraction of parts made by conventional methods. Especially when produced in quantity by our time-proven direct cladding methods, four-slide presses and custom designed welding equipment.

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COMPONENTS DIGEST

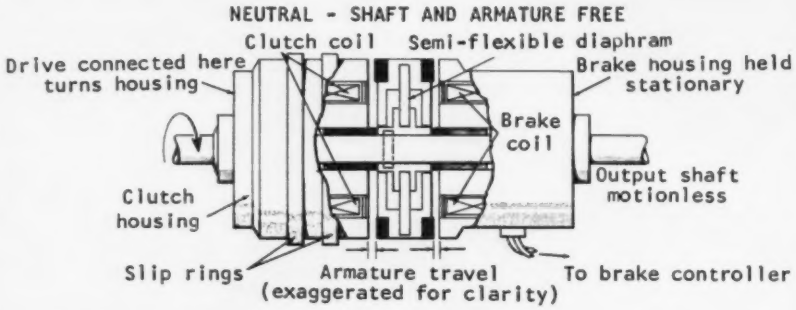

Fig 1 Typical clutch-brake, manufactured by Simplatrol Products Corp., for high response systems employs their patented semi-flexible diaphragm operation — no plate sliding on splines or pins. In this clutch-brake combination there are three assemblies — clutch magnet, a brake magnet and an armature. Armature is keyed or pinned to output shaft. Body of the armature, which has a friction facing on both sides, attaches to outer diameter of diaphragm, while armature hub fastens to inner diameter of diaphragm and in turn attaches to shaft. Clutch magnet is driven from power source; when its coil is energized armature body is attracted to it, the diaphragm deflecting to allow the friction face to contact the clutch. Armature hub is held in place on output shaft, therefore, there is no sliding action between metal parts. Torque is transmitted from clutch, through friction face, through diaphragm to shaft. De-energizing the clutch coil returns the armature to its disengaged position, and the shaft coasts to a stop. To obtain braking action, the brake coil is energized when the clutch is de-energized; the armature then deflects and contacts the brake magnet which is anchored to a stationary member. Stopping and/or holding torque is thereby transmitted through the diaphragm to the shaft. Simplatrol's diaphragm construction is used in a range of clutches from under one inch diameter to 12½" diameter; from torque ratings of ten ounce inches to 470 pound feet.

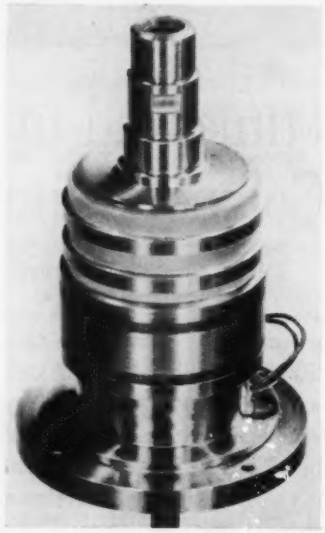

Fig 2 Clutch-brake unit used in RCA's electromechanical printer for their 501 data processing system. The Simplatrol CB-62, an adaptation of their standard CB-60 clutch-brake, accelerates and positions the paper for each line of printing. This clutch-brake piles up 600 complete operations per minute (including the stop time while the line is being printed with the paper at rest). It holds the position from one line to the next to within 0.005 — without the aid of any positive stops. Due to the flexible diaphragm action, when the clutch is engaged, there is no metal-to-metal contact, only smooth friction material against smooth metal face, producing a consistent torque output no matter where contacted. The clutch is also used in the tape drive section of the RCA 501 system. Smoothness and quietness of the clutch-brake was a major factor for its use in this business machine.

these if the clutch were further up in the system.

In cases where indexing accuracy is not a requirement there is an advantage in placing the clutch closer to the prime mover, assuming this gives higher speed. The lesser torque required allows use of a smaller clutch. However, this must be weighed against the effect of starting and stopping of the members between the clutch and the load increasing the energy transmitted through the clutch brake or friction facing at each start or stop which in turn increases the heating and wear. The choice then becomes largely a function of the cycle rate. • • •

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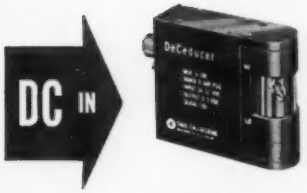

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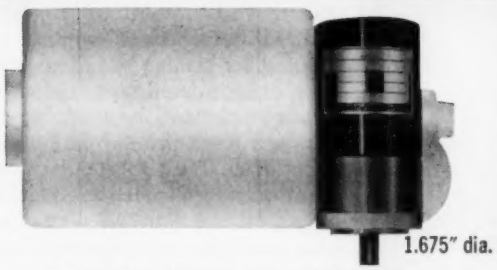

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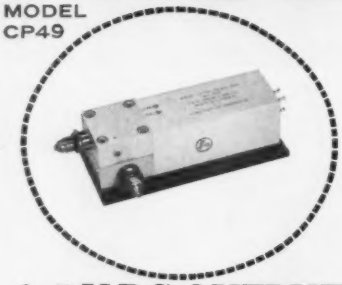

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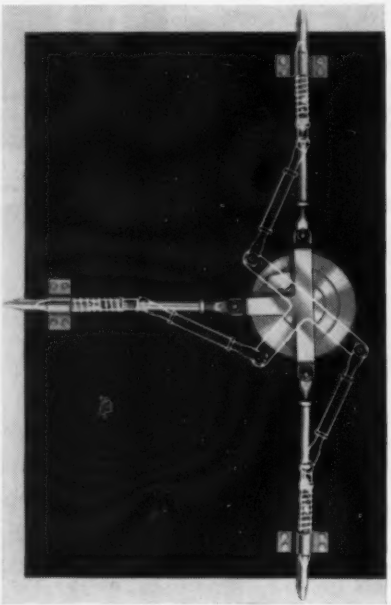
New Components For Electromechanical Systems

Miniature Reed Relays

Encapsulated reed relays have up to 12 poles in a package only 2-⅛″ long (including leads) x 19/32″ deep x 1-25/32″ wide. A 1-pole type is only ⅜″ dia. by 2-⅛″. Matching 2-and 4-pole types are similarly miniaturized, light in weight and designed for maximum reliability on light load and dry circuit switching for hundreds of millions of operations. Operating elements of the relays are miniature dry reed switches glass-sealed in an inert gas. Standard units have 6 volt dc operating coils and require approximately 0.2 watts per pole. Contacts are normally rated 5 watts resistive load with maximum life obtainable at dc voltages of 12 or less. Struthers-Dunn, Inc., Pitman, N.J.

Write No. 326 in Box on Inquiry Card



Electronic Hardware

A line of closing, latching, locking and door-bolting hardware for electronics cabinetry features the compactness, lightweight and strength required in aircraft applications. Made primarily of stainless steel and aluminum alloys, products include: flush latches for horizontal or vertical installation in metal cabinets and on hinged panels, doors or drawers; door-bolting systems that prevent entrance or escape of moisture, dust and air; and quick release over center latches for fastening covers, panels and hatches, or for cinching a compression gasket seal. Adams Rite Mfg., Co., Glendale, Calif.

Write No. 484 in Box on Inquiry Card

Milled Grid Thyratrons

Exclusive milled grids for thyratron tubes bids well to revolutionize the control of pulsating circuits. For many years, the big problem in these tubes was to get two or more that were balanced in performance characteristics. With conventional grids it was necessary to test and check many tubes to select balanced sets. With a milled grid, this is no longer required; every tube is always constant in characteristics. Half-wave, xenon filled, grid controlled thyratron rectifier tubes, available with these milled grids, are ideal for control circuits in welding equipment, static spray equipment, induction heating, motor control, variable voltage power supplies and other difficult pulsating circuits. Tubes meet all mil spec requirements. Cetron Electronic Corp., Geneva, Ill.

Write No. 451 in Box on Inquiry Card

Printed Circuit Pin Terminals

Two new pin terminals designed for any 0.040 socket, such as a miniature tube socket have pin lengths of 0.300 and 0.150 inches. Both parts have three staking shank lengths of 0.051, 0.082 and 0.113 inches. The terminals may be used for staking to boards which are later encapsulated and individual pin arrangements can be made so that the standard tenth printed circuit grid may be utilized. Built to stand rugged use, these pins are precision machined in brass and are finished with hard gold over silver plate. Cambridge Thermionic Corp., Cambridge, Mass.

Write No. 314 in Box on Inquiry Card

High Speed Scalers

Complete high speed scalers only 0.242 cubic inch in size are being produced by Paraplegics Mfg. Co., Inc., Bensenville, Ill., a company owned and operated by physically handicapped men and women. The scalers are modular in design and embody printed circuits complete with resistors, diodes and transistors. Heat sinks are employed to protect components during soldering operations. Following assembly, the units are checked for output voltage and wave form with a square wave generator. The unusual dexterity of the physically handicapped enables them to specialize in precision operations on subminiature products.

Write No. 411 in Box on Inquiry Card

Linear Potentiometer

New, ½" dia potentiometers differ from conventional types in that the resistive element embodies a solid raised track of conductive plastic, integrally co-molded together with terminals and taps to an insulator base of high temperature phenolic resin of matched thermal expansion coefficient. The potentiometers have low electrical noise, virtually infinite resolution and withstands vibrations as well as shock loadings in excess of 100g. Markite Corp., New York, N. Y.

Write No. 471 in Box on Inquiry Card

Hi Temp Magnet Wire

Employing a cross-linked polymer for insulation, high abrasion-resistant magnet wire operates continuously at temperatures exceeding 260C. Its tough yet thin insulation overcomes the problems of poor abrasion, cold flow, and resistance to impregnating and potting encountered with other high temperature insulations. In tests conducted to MIL-W583B, the wire performed as high as 275% (average 169%) above the minimum requirements. Abrasion resistance averaged 750% above the minimum. In the stability test, voltages of 550% above the minimum were required to break down the insulation. Hitemp Wires Co., Westbury, N. Y.

Write No. 306 in Box on Inquiry Card

Micro-Miniature Thermocouples

"World's smallest and most sensitive temperature sensors" meet the demand for fast, accurate temperature measurement instrumentation in the range from cryogenic environments to +3000°F. Its capabilities result from the small size of the thermocouple wire plus a variety of hot junction configurations. A response time of 13 msec has been achieved with the exposed junction configuration. Typical applications include rocket fuel temperature measurement, skin temperature on missiles and high speed aircraft and gas chromatography. Baldwin-Lima-Hamilton Corp., Waltham, Mass.

Write No. 512 in Box on Inquiry Card

not recommended for hi-fi enthusiasts

(Although we don't have too many reasons why it isn't.)

Just because the frequency response of our new 6 watt transistorized servo amplifier is extra good, someone had to suggest its use as a HI-FI component. He proved his case, too, by playing MANTOVANI through it without losing a string!

Actually, the exceptional bandwidth which permits its operation on either 60 or 400 cycle carriers is only one of many features that make this amplifier outstanding.

Low dynamic output impedance insures good linearity and minimizes distortion between "motor-line performance" and "motor-amplifier performance".

High (30K) input impedance permits operation from most of the common input sources.

And high reliability has been achieved without the finality of potting; aluminum oxide particles provide good thermal conductivity at the same time affording protection against adverse environments.

For additional information on this servo amplifier No. TA006-0A-100 write: Diehl Manufacturing Company, Somerville, New Jersey.

SPECIFICATIONS

Cat. No.	TA006-0A-100
Output	Continuous; 10 watts, max. (unmounted, in free air at 25°c ambient, no heat fins) 4 watts, max. (mounted on 12 x 12 x ⅛" aluminum plate, at 71°c ambient, with ¼" heat fins)
Gain	1000 volts/volt, nominal
Input Imp.	30K minimum
Phase Shift	a) No measurable phase shift in 20 cps passband for 60 cps carrier. b) Less than 10° phase shift in 100 cps passband for 400 cps carrier
Noise	.013 volts, input shorted
Power Req.	−28 ± 2 volts DC at .600 amp.; +9 ± 1 volts DC at .015 amp.

Diehl†

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NEW COMPONENTS

Analog To Digital Converter

Precise, shaft-position, optical (non-contacting) analog-to-digital encoder provides 8192 (2^{13}) codes per revolution without gearing. Modular plug-in components and self-contained spares enable field servicing without special tools or soldering devices. Provision is made for "go-no-go" testing from a remote location and for monitoring operation during a mission. Wayne/George Corp., Boston, Mass.

Write No. 463 in Box on Inquiry Card

DC Drive Amplifier

Designed to drive dc torque motors, now coming into wide use, a fully transistorized amplifier delivers 2 amps dc differential current into two terminal torquer. Input into amplifier can be either dc or 40 cps. Sample gain: 200 mv per 1 amp dc output current. Current feedback minimizes effects of torquer inductance on servo response. Unit operates from standard 28 v dc power. Control Technology Co., Inc., New York, N. Y.

Write No. 455 in Box on Inquiry Card

Step-Servo Drive

A drive unit designed as a position actuator, operating with step-servo controllers and pulse sources, controls autotransformers independently of line frequency. Because the step-servo drive operates open loop without overshoot, systems incorporating this bi-directional device do not require the compensation of conventional servo-mechanisms. Time for full scale travel, stepping increments and number of autotransformers actuated by a single drive unit varies to suit particular requirements. Automation Development Corp., Culver City, Calif.

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High Acceleration Servo Motor

Size 8 servo motor has a low moment of inertia of 0.147 gram-gm^2, giving an extremely high theoretical acceleration of 106,000 radians/per sec^2. Its very low time constant of 0.00613 seconds provides very rapid response in servo systems. Weight is 1.25 oz, average; diameter, 0.75 inch; temperature range, ambient, is –55°C to 125°C; stall torque, 0.22 inch-ounces. Unit meets Mil-E-5272. Wright Machinery Co., Durham, N.C.

Write No. 337 in Box on Inquiry Card

Pulse Generating Modules

New continuous pulse train generating modules act as pulse sources for step-servo motors and controllers for digital control applications. They operate on 28±5 vdc (160 ma max). All other output parameters are predetermined and match step-servo controller input requirements. Pulse ranges from 4 to 16 pps up to 65 to 300 pps. Max weight: 2 oz. Automation Development Corp., Culver City, Calif.

Write No. 542 in Box on Inquiry Card

Latching Relay

Designed to lie flat on printed circuit boards, a dual-coil, microminiature relay, 0.485″ in height, enables close stacking of circuit boards. Remaining firmly latched in either armature position without applied coil power, it reduces power supply drains of equipment using relays with long "on" times. It operates on a 3 millisec pulse at a nominal voltage at +25°C. Designed to operate in severe environments such as those encountered in missiles, the FL meets all applicable sections on Mil-R-25018, Mil-R-5757C, and ABMA-PD-R-187. Potter & Brumfield, Princeton, Ind.

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Precision resistors contain special internal flanges to securely fasten axial wire leads to resistor body, thus guarding against structural failure during assembly or subsequent use. Units come encapsulated in epoxy resin and meet MIL-R-93B for operation at ambient temperatures of 125°C. Sizes: from ⅛ to 3/16" dia and from ¼ to 1" long. Power dissipation: from 1/20 to ½ watt for largest styles. Shallcross Mfg. Co., Selma, No. Carolina.

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Micro-Diodes

The first "true hermetically-sealed" micro-diodes are said to offer a degree of reliability not possible to obtain consistently with earlier micro-diodes. High temperature glass is melted directly around diode to assure a hermetic seal, thus solving the problem of having silicon withstand direct contact with molten glass during manufacture. Operating and storage temperature range: —55 to +150°C; max power dissipation at 25°C: 100 mw; Zener voltage: between 5.1 and 10 v at 5 ma. Transitron Electronic Corp., Wakefield, Mass.

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Cabinet Cooling

Twinpax, a new concept in cabinet flushing fans, offers many advantages such as large air delivery, directed air flow, low noise level, minimum vertical space requirements and high efficiency filtering. Two fans, working in parallel, produce a delivery of 450 cfm free delivery, or 400 cfm at 0.1" wg static pressure, — when operating on either 208 vac 60 cps 3 phase or 115 vac 60 cps 1 phase power. The fans are placed at an angle in the assembly, thereby directing the air flow at the most advantageous path minimizing "dead spots" and eddying within the cabinet. The twin fans are noise-insulated from the metal assembly by means of a special material. Rotron Mfg. Co., Inc., Woodstock, N.Y.

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Silicon Rectifiers

Stud-mounted rectifiers deliver up to 20 amps at 150°C in half-wave circuits; 60 amps in full wave circuits. Designed for power rectifier and mag-amp applications, the double-diffused, silicon junction units' peak inverse voltages vary from 50 to 800 PIV. Trans-Sil Corp., Englewood, N. J.

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Synchro Receiver-Brake Combination

Mil type unit consists of a synchro-receiver and an integral brake which locks receiver in position. The synchro may then act as a transmitter. Receiver consists of a 26 v, 400 cycle synchro with 1.5° accuracy under all environmental conditions and an integral brake solenoid available with 35 vdc, or 115 vdc. Length: 2 3/16"; dia: 1 1/16"; weight: 4½ oz. John Oster Mfg. Co., Racine, Wis.

Write No. 332 in Box on Inquiry Card

Analog-Digital Converter

Converting five million independent samples per second, an analog-digital converter has an accuracy of better than ±0.4%. The model is assembled on printed circuit boards which plug into a module shelf. The basic circuitry is built up with only seven basic sub-modules. All solid state components are used throughout. Analog input impendence up to 20,000 ohms ±10%; full scale input voltage is 1 v. Digital output format is parallel seven binary digit, presented on seven lines plus a timing signal on an eighth line. A pulse on any line signifies a "one"; no pluse signifies a zero. Raytheon Co., Waltham, Mass.

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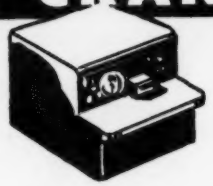

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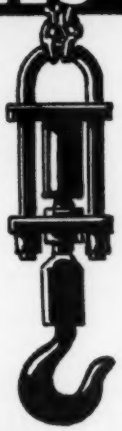

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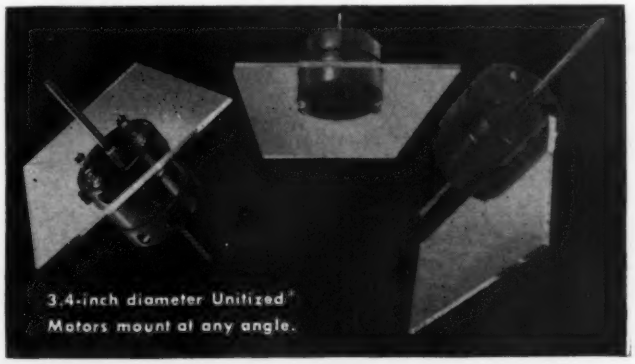

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synchronous motors

(Geared or Ungeared in ¾" dia.)

Kollsman's new Size 8 Synchronous Motors have a high "precision to ruggedness" ratio . . . were specifically designed for small space and light weight. Ungeared unit weighs only 1.25 oz. ■ These subminiature units are ideal for high reliability, high-performance applications in computer systems, camera drives, scanning devices, and other missile/avionics equipment. ■ Measuring only .960" length (ungeared), 2 5/32" (geared), the new Size 8's feature a synchronous speed of 8,000 rpm with a 400 cps input: source voltage is 55 volts; total power input is 5 watts; pull-in torque is .025 oz. in. Gear boxes available in ratios from 5:1 to 20,000:1. ■ You can now design your equipment or system smaller and better with a Kollsman Motor. Kollsman sales engineers are ready to assist you whatever your motor design needs. Take advantage of their experience which covers over 1,000 motor designs . . . which will save you time and money.

OTHER PRODUCTS: SYNCHROS • RESOLVERS • SERVO MOTORS • MOTOR GENERATORS • INTEGRALLY GEARED UNITS • INDUCTION GENERATORS • DRAG CUP MOTORS • SYNCHRONOUS MOTORS • PERMANENT MAGNET GENERATORS • VELOCITY AND INERTIA DAMPED UNITS . . . AND SPECIAL DESIGNS.

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CIRCLE NO. 50 ON INQUIRY CARD

NEW COMPONENTS

Subminiature Accelerometer

Subminiature piezoelectric accelerometer permits many in-flight tests that normally could not have been conducted with standard size or miniature size pickups. The Model 606 is a stainless steel accelerometer only ¼" high, weighing just 1.0 gram. It has a sensitivity of 2.5 pk-mv/ pk-g and a frequency response of 5 cps to 10 kc. Maximum acceleration is given at 40,000 g, amplitude linearity ±2%, and temperature range −65 to 300 F for standard units and −65 to 500 F for high temperature units, with less than ±10% variation in sensitivity throughout both temperature ranges. Columbia Research Labs., Woodlyne, Pa.

Write No. 729 in Box on Inquiry Card

Electronic Integrator

Lectrocount, an electronic integrator for direct operation from a millivolt signal offers the advantages of null balance stability, ability to follow a rapidly changing input signal, output counts of up to 10,000 per minute and capability of integrating by monitoring input without using a recorder. Models for speeds of 1000 counts per min. or less have an indicating counter and the output consists of dry contact closures. It is claimed that accuracy is unaffected by normal variations in line voltage and room temperature and that no adjustment is required for long periods of time. Royson Engineering Co., Hatboro, Pa.

Write No. 724 in Box on Inquiry Card

Static Relay

Solid-state static relays' design provide a new approach to "failure elimination" in systems where optimum relay performance is mandatory. Units have positive snap-on, snap-off action, but no contacts or points of any kind to corrode, wear, or "jar" open or closed. The relays can be mounted in any position and the design is such that the actuating and load circuits are isolated from each other. Although this relay was designed primarily for airborne applications, other models and modifications can be made for data processing and computer systems, material handling systems and other systems. Model SRIA-1 measures 2" x 1½" and weighs 0.4 lbs; turn-on time is 100 microseconds maximum with a signal voltage of 5 to 28 volts dc applied; control power is 0.004 watts. Magnetic Controls Co., Minneapolis, Minn.

Write No. 361 in Box on Inquiry Card

Micro-Miniature Capacitors

Claimed to be the smallest non-polar solid tantalum capacitor made, unit's size is 0.100 x 0.090 x 0.065 max. Actual weight tests show that more than forty of them equal the weight of one cigarette. aVlues range from 0.001 to 0.0047 mfd which operate at 50 vnp and from 0.0068 to 0.047 mfd at lower voltages. They operate at full-rated voltage from −55 to +85°C. Components, Inc., Biddeford, Me.

Write No. 364 in Box on Inquiry Card

Tape Reader

High-speed perforated tape reader operates on loops or strips of tape. A bi-directional spooler is available at speeds up to 300 characters per second, with eight in. reels. Part of the completely transistorized circuits are two flip-flops which provide reliable control of the four solenoids used to control start and stop in either direction. The photoelectric reader senses tape perforations by means of silicon photodiodes which are set permanently in the head, with the diode lens protruding. The self-cleaning effect prevents accumulation of lint and the possibility of reading errors. The polishing of the paper or Mylar against the lens improves sensitivity. Digitronics Corp., Albertson, N.Y.

Write No. 692 in Box on Inquiry Card

Acceleration Switch

An acceleration sensing switch operates in the low milli-G-range. Gas damping provides proper time delay or integration before switch closes. No heaters are required and there is no warm-up time because gas damping works virtually independently of temperature. Normally mounted level, unit can be used as a tilt switch since its threshold value equals a tilt angle of 8½°. Kearfott Div., General Precision, Inc., Little Falls, N. J.

Write No. 535 in Box on Inquiry Card

Lightweight Power Supplies

A transistor-regulated power supply for use in lightweight, miniaturized equipment weighs one pound, handles 115 volts, 400 cycle input voltage and delivers 20 volts dc, continuously adjustable over a 10% range with an external potentiometer. The complete model measures 2⅞" x 2½" x 4⅛". It operates at ambient temperatures from 0°C to 65°C. Short circuit protection prevents the power supply from damage when output terminals are shortened. Hycon Mfg. Co., Pasadena, Calif.

Write No. 534 in Box on Inquiry Card

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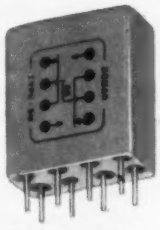

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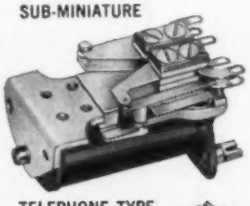

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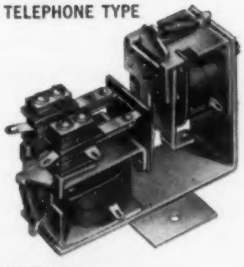

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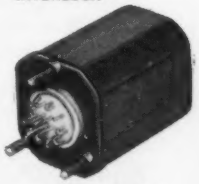

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CIRCLE NO. 51 ON INQUIRY CARD

• HARDENED PINIONS
• 125°C AMBIENT
• HIGH TORQUE

BOWMAR

Precision Servo Motors

SIZE 8

Five basic types—Plain or hardened pinions—Tapped holes on mounting faces — Split, center tapped or plain control phase windings for 26 or 36 volt operation—26 volt fixed phase. All types have .35 In.-Oz. minimum stall torque.

SIZE 10

Six types available—26 or 115 volt fixed phase—Split, center tapped or plain control phase for 26 or 36 volt operation. High compression glass molded terminals, extremely shock resistant, meet high altitude specifications. High torque throughout ambient temperature range.

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You get exclusive "one-stop" capability in Servo Motors and Servo Motor Assemblies from Bowmar. You may obtain motors alone, or **wedded** with precision Bowmar **Gearheads**, multispeed "ELECTROSHIFT" **Gearchangers** and other components. They are also available in complete Bowmar-designed **Servo Packages.** All Bowmar Servo Motors have slotted shafts at terminal ends to facilitate checking of total lost motion (backlash) AFTER assembly to other components. Electrical and mechanical characteristics of all Bowmar Servo Motors may be changed to meet customer requirements.

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CIRCLE NO. 73 ON INQUIRY CARD

NEW COMPONENTS

Silicon Power Supply

At 71°C ambient air, an all silicon power supply performs continuously at full load, maximum line. It uses convection cooling with no blowers or moving parts. Entire circuit of semiconductors gives almost twice the efficiency of comparable vacuum tube supplies, according to the manufacturer. Transformer and choke are hermetically sealed and meet the requirements of Mil-T-25. Computer grade capacitors are used in all filter circuits, and remote sensing is provided. Finely adjustable potentiometer and circuit breaker protects against short circuit and overload and regulator circuit prevents semiconductor damage. A voltmeter and a milliameter are on the front panel. Line regulation is less than 0.05% change in output voltage for input variations from 105 – 125 volts ac. Load regulation is less than 0.1% change in output voltage for load variations from zero to full load. Ripple and noise is less than 5 millivolts rms. Power Sources, Inc., Burlington, Mass.

Write No. 308 in Box on Inquiry Card

Multiple Diodes

Consisting of two or three semiconductor diodes packaged as single integrated units, multiple diodes are expected to simplify the assembly of computers by reducing the number of separate components and electronic connections. The small, individual, two-terminal devices translate complex questions, into computer language, by reducing them to a series of "yeses" and "noes". Characteristics include: forward voltage drop at 5 milliamperes – 0.4 volts max., reverse breakdown voltage – 20 volts, reverse current at 2 volts (55°C junction temperature) – 15 microamperes maximum, a 0.25 microsecond maximum recovery time when switching from 20 milliamperes forward current to 6 volts reverse bias. Radio Corporation of America, New York, New York.

Write No. 300 in Box on Inquiry Card

Paper Tubular Capacitors

Providing ruggedness and moisture- and heat-resistance approaching those of a molded capacitor, a new capacitor achieves its characteristics principally through a "triclad" tube – a kraft exterior bonded to a foil-film shield. Ratings of 0.001 through 1 mfd., at 400, 600, 1000 and 1600v are available. Dimensions range from ¼" x 1" to 1" x 2⅜" Wide range of applications includes dc, ac, and pulsed dc. Capacitor operates over temperatures from –40 to +125°C., with no derating. Cornell-Dubilier Electronics, Newark, N. J.

Write No. 302 in Box on Inquiry Card

Explosion-Proof Potentiometer

Encapsulated molded-composition potentiometer for explosion-proof and waterproof applications incorporates a patented perimeter track which allows the unit to be rated at three watts for standard applications and two watts for military specifications (MIL-R-94B). With a maximum operating temperature of 125°C and a life of 100,000 rotations under full load, the pot's resistive values range from 100 ohms to five megohms, with a tolerance of 10%. Reon Resistor Corp., Yonkers, N. Y.

Write No. 310 in Box on Inquiry Card

Long-Life Commutation Switch

Miniaturized commutation switch handles 180 channels of information with a plate only 1¾ inches in diameter. The plate, made from Supramica 555 ceramoplastic with superhardened gold-plated contacts, operates efficiently in temperatures as high as 650 F. Metal brushes are mounted in nylon to eliminate bounce and give sharp, clean signals. Metal-to-metal wiping action eliminates the problem of graphite build-up on the contacts. The switch can be driven at up to 1,800 rpm. Noise level is less than a millivolt when 5-volt signals are switched into a 150-ohm load. Mycalex Electronics, Clifton, N. J.

Write No. 301 in Box on Inquiry Card

Size 8 Servomotor

Incorporating a low inertia rotor and high torque output, size 8 servomotor eliminates the need for damping tachometers in specific applications. In positioning servos, where a fairly high amplifier gain is necessary due to high sensitivity or high dynamic response requirements, the new motor's high torque-to-inertia ratio (theoretical acceleration of 130,000 rad/sec^2) may often suffice for stable performance. No load speed is 10,000 rpm, stall torque — 0.35 min., and max. power output is 0.6 watts. Other features include 115 volt windings, fully encapsulated, low temperature rise and high efficiency. Daystrom, Inc., Worcester, Pa.

Write No. 304 in Box on Inquiry Card

Micro Miniature Resistors

Performance characteristics of resistors, 0.135″ long and 0.050″ in diameter, compare to those of much larger metal film resistors. Units are rated ⅛ watt, 250 volts in an ambient temperature of 100°C, and derated to zero load at 150°C. They cover the range from 25 ohms to 110k ohms at either 1% or 2% tolerance. Leads of soft, tinned copper are 1″ long and 0.016″ in diameter. Highly resistant to oxidation, impervious to moisture and high humidity conditions, the noble metal film resistors are unaffected by low temperatures and to temperature cycling between −55 and +150°C. Temperature coefficient may be selected at either 50 or 100 ppm/°C, or on special order at 25 ppm/°C. American Components, Inc., Conshohocken, Pa.

Write No. 305 in Box on Inquiry Card

Minuteman Transistors

Motorola's reliable mesa switching and amplifier transistors, developed specifically for the Air Force Minuteman missile, are now available for other critical military applications. Reliability goal for the transistors is a (guaranteed) failure rate of less than 0.0007% per thousand hours. A high speed mesa computer transistor with a current-gain-bandwidth product of 350 megacycles, the 101B is furnished with all test data corroborating the reliability specs. The identical transistor (101A) is available without the substantiating data at somewhat reduced cost. Type 201, a companion transistor for amplifier applications having similar characteristics, is also available with subscripts A and B denoting a price structure which depends upon the substantiating data supplied. Motorola Semiconductor Products Inc., Phoenix, Ariz.

Write No. 548 in Box on Inquiry Card

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The ultimate in precision differentials for computer applications. Available from stock in single and double pinion models. Hollow shaft design and readily interchangeable end-gears simplify field installation and maintenance.

Specifications: *Speed:* Up to 10,000 r.p.m. *Torque:* To 32 in-oz. *Starting Torque:* 0.01 in-oz. *Backlash:* As low as 1.5 minutes of arc. *End gearing:* Completely interchangeable.

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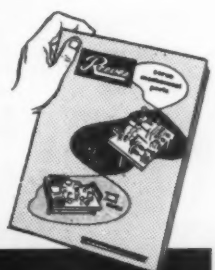

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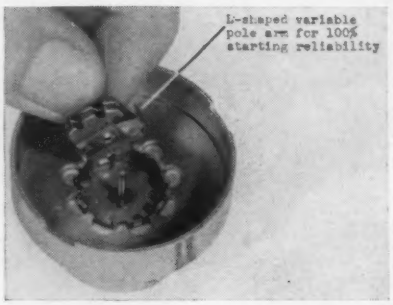

Variable Pole Synchronous Motor

Constant speed motor uses an L-shaped variable pole arm to prevent failure in starting because of being on dead center. According to company engineers, this permanent magnet motor is the only one on the market with this important engineering feature. The small L-shaped arm, an inexpensive stamping, is riveted on the rotor. If rotor poles should possibly stop on dead center, magnetism induced in the variable pole arm by the field coil starts rotor into motion. This gives both permanent and alternating polarity to the rotor. Lake City, Inc., Crystal Lake, Ill.

Write No. 527 in Box on Inquiry Card

Self-Locking Insert

In fastening applications up to 1200°F, a self locking insert eliminates seizure and galling. The insert attains its unique locking effect from a "grip coil" midway in its length which renders unnecessary the use of lock-nuts, lock-washers and lock-wiring. The bolt, when screwed through the threads of the insert, forces the flat chords of the "grip coil" to conform to the usual thread shape; the chords maintain a uniform locking effect on the bolt, even after repeated use. Heli-Coil Corp., Danbury, Conn.

Write No. 536 in Box on Inquiry Card

Silicon Controlled Rectifier

Miniature "Thyrode" silicon controlled rectifiers weighing 1/10 oz. can replace mechanical relays where load currents of one amp are required. Units have peak reverse voltage ratings of 20, 30, 50, 70, 100, 150, and 200 volts. The low operating current range permits highly efficient power switching on such applications as computer circuitry, temperature control, servo-mechanisms, ac and dc motor control and airborne printed circuitry. International Rectifier Corp., El Segundo, Calif.

Write No. 706 in Box on Inquiry Card

Silicon Rectifiers

Encapsulated silicon rectifiers, rated at 600 volts maximum peak reverse voltage, can be used at up to 420 volts rms in resistive and inductive circuits, and up to 215 volts rms on capacitive loads. Rated at 750 milliamps continuous at 50°C and 500 milliamps at 85°C ambient, the units can be stored at temperatures from −55 to +100°C. Full load forward voltage drop, full cycle average at 85°C, is 0.5 volt; maximum leakage current is 250 microamps. Rectifiers have passed four times the humidity test requirements of Mil-202A method 106 for hermetically sealed units. P. R. Mallory & Co. Inc., Du Quoin, Ill.

Write No. 313 in Box on Inquiry Card

Linear Transformer

Capable of delivering ½ watt into a 500 ohm load, size 8 linear transformers retain 0.33% linearity over ±30° range; over ±50° range for 3000 ohm load. It has a 26 volt, 400 cycle input, with phase shift control capabilities to ±30'. Unit meets mil spec requirements for 1200 hours rotational life and all conditions of Mil-E-5272 and Mil-E-5400. IMC Magnetics Corp., Maywood, Calif.

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- Seasoning
- Testing

Seven Revco cabinets, both chest and upright styles, are available. Capacities range from 1.5 to 6 cu. ft. in chests and to 22 cu. ft. in uprights. Units provide temperatures to −140° F. controllable within ±1°. Optional accessories are offered. Immediate delivery on all units.

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AN INSTRUMENT TRANSMISSION FOR PRECISE MULTIPLE SELECTION OF SHAFT SPEEDS

Versatility of ten ratios . . . to 1000:1! Desired shaft speed can be quickly selected at the turn of a dial, without stopping the input shaft. Geared design provides exact repeatability and non-slip drive . . . ideal for new instrument design, breadboards, general laboratory applications.

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INSCO COMPANY
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GROTON, MASSACHUSETTS

CIRCLE NO. 56 ON INQUIRY CARD

Microminiature Relay

A dc magnetic latch relay with rotary balanced construction maintains actuated condition without continuous power drain and provides excellent stability and long life. SPDT sensitivity at pull-in at 25°C is 150 MW or better; DPTD 300 sensitivity or better. Optional terminal arrangement of long or short leads for printed circuit boards or hook terminals for standard wiring are available. Hi-G, Inc., Windsor Locks, Conn.

Write No. 351 in Box on Inquiry Card

"Silent" Solenoid

Close tolerances between plunger and plunger cavity, in solenoid design eliminates cycle chatter common to ac solenoids. Unit incorporates a relief valve mechanism which opens at 21 psig and has zero leakage from 0 – 15 psig. Operating continuously at 225°F ambient air temperature and weighing only 0.34 lbs., the solenoid produces a force of 1.3 lbs. at a stroke of 0.025 ins. It measures approx. 1.375" x 1.435", and requires 108/121 vac at 384/420 cycles. Meets Mil-S-4040. Rocker Solenoid Co., Wilmington, Calif.

Write No. 311 in Box on Inquiry Card

Rotary Tap Switches

Conservatively rated to break 1 amp at 115 vac (resistive circuit) and to carry 5 amperes, midget tap switches indicate a life expectancy of 100,00 cycles. The single deck, single pole enclosed rotary switch can be provided with 2-6 positions, with stops standard on 2-5 positions, and 6 positions normally supplied as continuous rotation. They incorporate 60° indexing with a stop strength of 10 lb-in, and a rotational torque of approximately 12 oz-in. Grayhill, Inc., La Grange, Ill.

Write No. 341 in Box on Inquiry Card

Constant Voltage Supply

Said to avoid all problems resulting from manual or "automatic" standardization, a voltage source eliminates the need for standard cells, mechanisms, batteries and associated components. It can replace the battery in any potentiometer recorder, requiring 6 ma or less measuring circuit current at nominal 1.029 vdc. The supply provides precise regulation with highly accurate temperature compensation. It can also be used for a bridge circuit power supply. West Instrument Corp., Chicago, Ill.

Write No. 450 in Box on Inquiry Card

Linear Actuator

Measuring 14 7/16" by 1¾" by 3 ¾" and weighing 3 lbs 14 ozs, a linear actuator uses a dc motor to operate a precision ball screw and provides 500 lbs over a 6" stroke. Rate of travel, fixed at 10 inches per minute, can be adjusted at the factory. Maximum allowable tension or compression load is 2500 lbs. Actuator meets specs for environment and radio noise shielding. Temp range: —65 to 300°F. Unit operates on 27 to 100 vdc; universal ac/dc operation is also available. Globe Industries, Inc., Dayton, Ohio.

Write No. 543 in Box on Inquiry Card

Silicon Controlled Switch

Silicon controlled switches offer firing control to within ±.08 v, a sensitivity of 20 ua firing and surge capability to 10 amperes. Handling peak recurrent pulse curents of 5 amperes, the new devices make possible miniaturization of squib firing circuits with no sacrifice in design margin. Their low 1 ma holding current level makes them particularly useful in programming, control, and logic applications. Mil-S-19500 capability is assured. Solid State Products, Inc., Salem, Mass.

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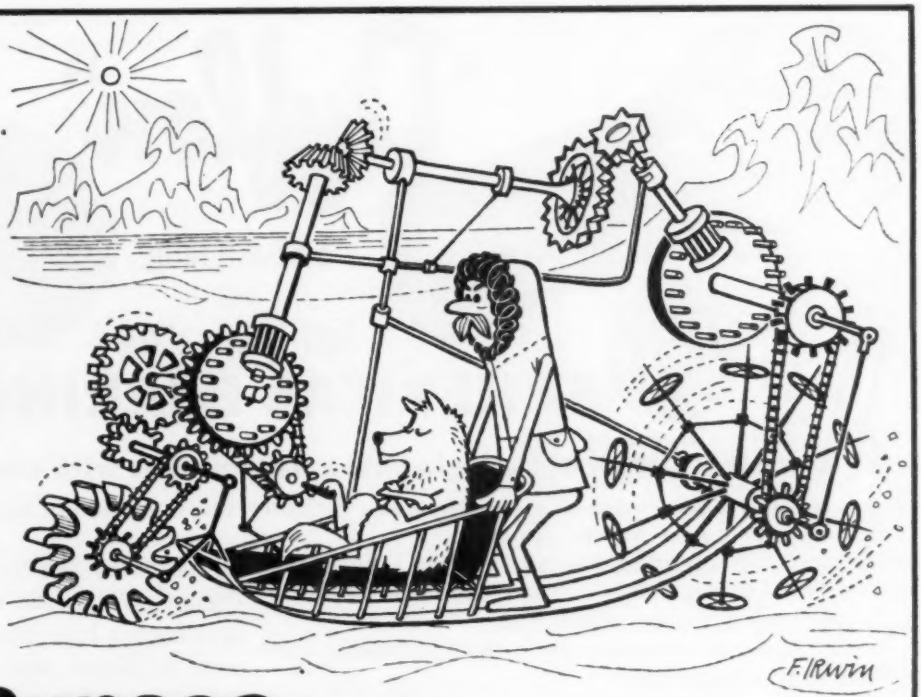

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CIRCLE NO. 61 ON INQUIRY CARD

NEW COMPONENTS

Miniature Relay

Magnetic reed relays less than one half the conventional size combine highly stable contact resistance over a long life with high switching speed. Their gold contacts, magnetically actuated, are hermetically sealed inside a glass capsule in an atmosphere of inert gas. Dimensions: relay body (coil) 7/8" long, 7/16" dia; over-all length with standard solder terminals, 1-1/2". Magnecraft Electric Co., Chicago, Ill.

Write No. 529 in Box on Inquiry Card

Frequency to Analog Transducer

With accuracy and stability guaranteed, transducer uses static elements to produce dc meter current directly proportional to input frequency or pulse rate. For standard 2½" D'arsonnal meter, accuracy is ±1% of full scale; for larger instruments, ±½%. Seven standard models cover the range 15 cps to 12,000 cps (to 100 kc upon request). Pioneer Magnetics Inc., Santa Monica, Calif.

Write No. 435 in Box on Inquiry Card

High-Speed Printer

A 26 column, completely transistorized, numeric printer serves as a system readout in checking the Skybolt missile. Forming a small package and able to operate under extreme environmental conditions, the unit operates at speeds up to 600 lines per minute, and has a self-contained paper supply and take-up. It gives a permanent, printed record as well as go, no go indications. Potter Instrument Co., Plainview, Long Island, N. Y.

Write No. 309 in Box on Inquiry Card

Miniature Cycling Timer

Hermetically sealed military timers provide accuracy and reliability under severe operating conditions within a range of 5 sec to 30 hrs. Newly designed 400-cycle and 60-cycle motors achieve compactness and light weight. Switch-actuated cams, precision-cut to cycling time requirements, give an accuracy of 1° at operating point of any one circuit or 2° between operating points of two circuits. Unit has met mil tests, including operation at 70,000 ft, vibration from 10 to 2000 cps at 20 G's, and 50-G 11-ms shock. Cramer Controls Corp., Centerbrook, Conn.

Write No. 518 in Box on Inquiry Card

Tachometers

Representing significant technical advances in dc tachometers, particularly along the lines of reducing armature inertia and overall weight and size, a new unit weighs less than 1¾ oz, has an overall dia. of ¾" and an armature inertia of 3.5 gm-cm². Other principle dimensions are identical to size 8 motor standards. Unit has the same linearity (1/10 of 1%) as larger units. With output of three volts per 1000 rpm and rms value of the ripple does not exceed 3% of the dc output. Servo-Tek Prod., Inc., Hawthorne, N. J.

Write No. 707 in Box on Inquiry Card

Electro-Pneumatic Converter

With an accuracy 0.5% of full scale a versatile unit converts dc voltage or current into pneumatic pressure signals. It accepts input signals of 1 to 9 v or ma dc; output ranges from 0 to 30 psi. A completely waterproof housing leaves the unit unaffected by ambient temperatures up to 120°F. Frequency response: 2.5 cps; repeatability: 0.1% of full scale; sensitivity: 0.025% of full scale. Hagan Chemicals & Controls, Inc., Pittsburgh 30, Pa.

Write No. 426 in Box on Inquiry Card

Combine "Monoball"® Engineering Advantages with Life-Time Lubrication

Design engineers in many industries are specifying new "DYFLON"® SELF-ALIGNING and SELF-LUBRICATING SPHERICAL BEARINGS for these 5 major reasons:

1. LOWER COEFFICIENT OF FRICTION
...ideal where lubrication is impossible or undesirable.

2. WITHSTAND EXTREME VIBRATION
...perfect performance under shock load conditions.

3. WILL NOT "COLD-FLOW"
...even under extreme load conditions.

4. IMPERVIOUS TO KNOWN CHEMICAL SOLVENTS
...eliminates corrosion problems.

5. FAIL-SAFE ...due to "Monoball"® design.

Request Engineering manual No. 551.

In addition, due to their two-piece "MONOBALL"® design and plastic alloy insert, "DYFLON"® bearings have a long cycle life. Alignment and installation problems are minimized. Oil-free for life means lowest possible maintenance costs.

Available in a variety of plain or rod end types. Bore sizes to 3.000". Materials include stainless steel, plastic alloys and chrome alloy steels. Ultimate static loads to 500,000 lbs.

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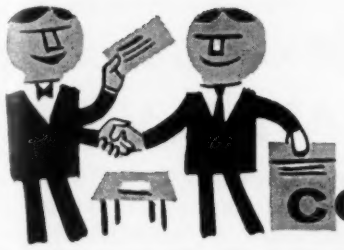

CONTRACTS

Now that we know that the moon isn't made of cheese (we know, don't we?), can we get the man in the moon to say cheese? Itek Labs. of Lexington, Mass., will conduct a research and study program intended to pave the way for the eventual development of cameras which can produce images of unprecedented clarity under the effects of severe space environment. The Laboratories' scientists will study the effects of environmental factors on a large, precision optical system which they will design and build to represent a typical high-performance aerospace reconnaissance sensor. "The operational requirements are such that the precision in optical equipment which we foresee will be more that of large astronomical telescopes than that of classical aerial cameras," Dr. F. Dow Smith, Dir. of the Labs.' Graphic Information Res. Div., declared. The Aeronautical System Div. of Wright-Patterson Air Force Base awarded a million dollar contract for this work.

Compatible techniques for the fabrication of integrated circuit functions will be explored by Motorola Semiconductor Products Div. under an Air Force contract totaling $1,473,094. Combining semiconductor processes and thin-film technology, Motorola will investigate epitaxial form control growth as a means of obtaining single-crystal circuit functions, abrupt junction formations, graded junction formations, P and N type layers of controllable thickness, formations of a multiplicity of P and N layers with controllable lifetime and impurity concentrations, and compatible masking techniques. The Semiconductor Div. will work jointly with Motorola's Solid State Research Lab. for research and development on the thin-film functions. Once feasibility of individual fabrication methods has been established, Motorola will combine specific functions into integrated circuit functional models.

Atomic movement in solids will be studied in the University of Arizona's solid state physics laboratory by Dr. Carl T. Tomizuka, professor of physics, under support of a one-year $39,000 renewable contract from the U. S. Atomic Energy Commission. A recognized authority on solid state physics research, Tomizuka will work with silver halide solids such as silver bromide in an attempt to demonstrate that "the mechanism of mass motion in solids will change when high pressure is applied. Behavior patterns of various known impurities in the otherwise pure metals will also be studied." Tomizuka will employ the high pressure technique, the radioactive tracer method, and electrical conductivity measurements of the solids. Extremely high pressures of up to 150,000 pounds p.s.i. can be applied to solids in the new U of A laboratory.

BRIEFLY:

Magnetic tape recorder/reproducers: $1,436,769 to Ampex Corp., Redwood City, Calif., from Navy Bureau of Ships.

Weapon systems: $40 million to Sanders Associates, Nashua, N. H.

Antenna equipment: $1 million to the Siegler Corp., L. A., Calif., for Air Force space and satellite programs.

Missile radars: $2,293,000 to Raytheon Co. from Convair/Pomona.

Computer connectors: $250,000 to Continental Connector Corp., Long Island City, N. Y., from Burroughs Corp.

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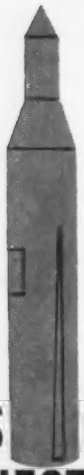

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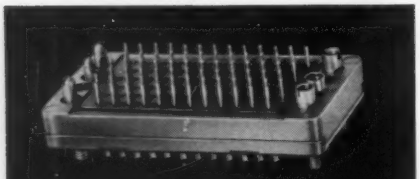

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For Your Literature File
NEW CATALOGS

Most of these catalogs contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the catalogs listed on this page, enter the appropriate number of the item on the Inquiry Card.

Power Supplies 975

Covering the latest development in regulated transistorized power supplies, catalog lists complete specifications and latest engineering features of units. Insert has a complete line resume of the major products of company. (6 pp). Harrison Labs., Inc., Berkeley Heights, N. J.

Miniature Flexible Couplings 985

Brochure combines data on ½, 5/8, ¾, 1, and 1½-inch O.D. couplings with both set screw and clamp type hubs. Graphs plot lateral deflection vs. flex force and torsional deflection vs. torque. Unit's leaf design allows misalignments with minimum resultant bearing pressures. (14 pp) Naugler Engineering, Inc., Beverly, Mass.

DC Power Supply 980

Power supply, in the 100-watt range, retains advantages of static-magnetic supplies and adds shunt type transistor control to provide a closer regulation of the dc output voltage. Brochure lists 10 advantages and discusses theory of operation. Sola Electric Co., Elk Grove Village, Ill.

Piezoelectricity 982

Principal existing and potential uses of piezoelectricity are discussed in a booklet that compares the performance characteristics of all major piezoelectric substances. Electromechanical properties and useful service temperature ranges of piezoelectric elements are also included. (16 pp). Clevite Corp., Bedford, Ohio.

Coaxial Relays and Switches 995

New catalog contains resume of the chief characteristics and operating principles of the coaxial switch and complete summary of 125 standard switches. Catalog enables the reader to quickly find the coaxial switch needed, together with all necessary information pertaining to it. (28 pp). RF Prods., Div. Amphenol Borg, Chicago, Ill.

Actuated Potentiometers 963

Summarizing key information on leadscrew and wormgear actuated potentiometers, brochure contains specs and prices on 13 models. Cutaway drawings illustrate outstanding features found in all models. These precision pots are used for matching, balancing and adjusting circuit variables in computers and telemetering equip. (4 pp) Bourns. Inc., Riverside, Calif.

Transformers 966

Listing almost 900 stock transformers, a catalog is said to be the first to offer such a choice of types. They range from units for high reliability military applications to low cost commercial transformers. Complete specs are given and, where applicable, performance curves are included. (34 pp) Chicago Standard Transformer Corp., Chicago, Ill.

R-F Impedance Plotter 970

Providing instantaneous display of impedance as a continuous function of frequency in the 10 to 3000 mc/s range, an impedance chart plotter is designed to supply peak accuracy with new speed and simplicity. Booklet explains how the instrument completely eliminates tedious procedures required by the slotted line technique by immediate display of load changes during network adjustments. The plotter gives VSWR uncertainty as low as 1.01. Oscilloscope trace may be directly photographed for permanent recording, or an X-Y chart recorder may be used. (4 pp) Dielectric Products Engineering Co., Raymond, Maine.

Magnetic Preamplifiers 984

The fundamentals of how to design low level and common mode isolation instrumentation and controls using magnetic amplifiers are explained. Described are amplifiers for thermocouples, strain gages, photocells, and other low level signals. (6 pp) Acromag, Inc., Southfield, Mich.

Resolvers and Synchros 959

Fundamental engineering data in easy-to-read form on 200 resolvers and synchros. Ten basic parameters are covered for each unit. A quick reference to the input voltage, impedance and transformation ratio values aid in the application of these high precision servo components. Units are grouped in terms of size and winding compensation. (6 pp). American Electronics, Inc., Instrument Div., Culver City, Calif.

Temperature Controls 992

Brief descriptions and specs are given for seventeen different types of temperature controls. Brochure is a handy reference folder for deciding on a controller best suited for a particular requirement. Covered are twelve thermo-switch units, six miniaturized local controls, four fire and overheat detection models, four snap action controls and seven electronic controllers. (8 pp) Fenwal Inc., Ashland, Mass.

For Your 3-Ring Binder
NEW DATA SHEETS

Most of these data sheets contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

Slip Rings 927

Described are the long-wearing, low-noise characteristics, plus other data, of several types of slip rings that incorporate solid and clad precious metals. Specific information that is needed to satisfy individual requirements is given. Metals & Controls Inc., Attleboro, Mass.

Telemetry Receiver 928

FM crystal controlled phase-lock telemetry receiver has a low noise figure of 6 db and a tuning range from 130-140 mc covering the recently assigned satellite band. Receiver mounts on a standard 19-inch rack and measures 8¾ in. high and 16⅛ in. deep Vitro Electronics, Silver Spring, Md.

Pressure & Density Control 929

Handy references for design engineers specifying environmental controls for measurement and monitoring are two tables that give standard pressures and densities for each 100 feet of altitude from 0 to 100,000 ft. Also included is information on environmental sensing and switches associated with monitoring and control of pressure and density. Newark Controls Co., Bloomfield, N.J.

Microcircuitry Techniques 907

A technical data sheet contains performance data on materials used in "thin film integrated circuitry." Data represent the result of extensive testing and indicates the practicability of constructing microcircuits on a production scale with present state of the art, materials and components. Halex, Inc., El Segundo, Calif.

Thermostats 932

Covering both hermetically sealed and semi-enclosed styles, 4-page data sheet gives full dimensional details, ranges, tolerances, differentials and Type A thermostat ratings. Uses include all types of heater controls and over-temperature protection subject to vibration and shock. Stevens Mfg. Co., Inc., Mansfield, Ohio.

Time Code Generators 905

Eight different time code generators for supplying missile and space vehicle instrumentation timing codes are listed in tabular form. Their outputs are depicted in pulse waveforms. Electronic Engineering Co., Santa Ana, Calif.

Mesa Transistors 922

Low saturation voltages and low input impedance of 8 new silicon mesa transistors make these devices suitable for high level linear amplifiers and general switching applications. Typical circuits include servo driver and output stages, pulse amplifiers, solenoid drivers and dc to ac converters. Although the transistors are designed for medium power applications (4 and 5 watts average continuous dissipation, maximum, with a case temperature of 25°C), the "A" versions will dissipate 20-watts peak power at 25°C with a pulse width of 0.8 milliseconds. General Electric Co., Liverpool, N. Y.

Size 23 Synchros 919

Detailed specs to aid in rapid selection of Size 23, 60 cycle thru-bore synchros for servo applications are given in data sheet. More than 25 characteristics are listed for transformers, transmitters, differential transmitters and receiver transmitters that all meet MIL-S-20708A. Vernitron Corp., Carle Place, N. Y.

Planar Acceleration Switch 920

Because a new acceleration switch is truly a planar device, an unlimited variety of vector patterns is possible and practicable. Units are in production with such vector diagrams as circular, offset circular, parallel extreme, square and elliptical. Almost any imaginable configuration, including re-entrant curves, can be produced. Aerodyne Controls Corp., Farmingdale, N. Y.

"Atomiclad" Contacts 921

New contact rivet is made by a new process which atomically bonds a noble metal contact surface to a rivet body of base metal. Data sheet explains how this technique produces a contact of superior physical and electrical properties at a lower cost. Gibson Electric Co., Delmont, Pa.

Resistor Modules 930

Wafer thin, miniature package containing four binary resistors provide any resistance value between 1 ohm and 1,222,221 ohms in 1 ohm steps. Called Resist-O-Stats, they are valuable in critical circuit design applications requiring precise resistance values and can also be used in determining unknown resistance values. Accuracies range from ±0.1% for values from 1,000 ohms to 1.1 megohm, to ±1% for low value resistors from 1 to 11 ohms. General Resistance, Inc., N.Y., N.Y.

ELECTROMECHANICAL DESIGN

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handbook 1

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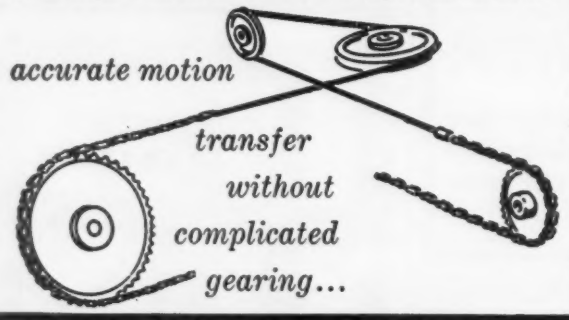

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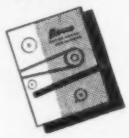

Contains useful application data, specifications, tables on chain pitch and sprocket sizes, suggestions for calculating center-to-center distance. *Write for yours today.*

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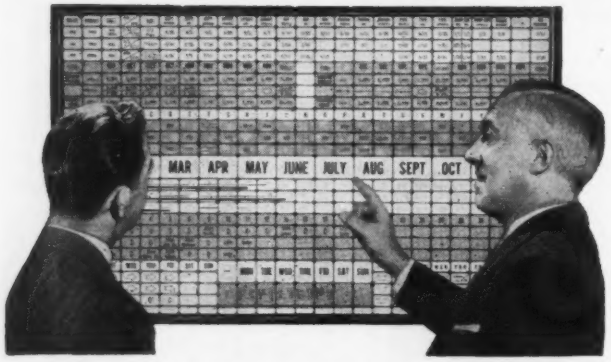

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CIRCLE NO. 58 ON INQUIRY CARD

ADVERTISERS' INDEX

ADVERTISERS	PAGE
A	
Automatic Electric Co.	10
B	
Barksdale Valves	26
Bowmar Instrument Corp.	72
Bristol Co., The	36
Bristol Motors	23
Div. of Vocaline Company of America	
C	
Clifton Precision Products Co., Inc.	Cover 4
Comar Electric Co.	71
Components Filing Service	66
Computer Instruments Corp.	1
Connecticut Hard Rubber Co.	55
Consolidated Controls Corp.	82
Controls Co. of America	9
Control Switch Div.	
Controlled Environment, Inc.	68
D	
Daven Company, The	Cover 3
Diehl Manufacturing Co.	67
Dynamic Gear Co., Inc.	75
E	
Eastern Air Devices, Inc.	33
Edcliff Instruments	65
Tavis Div.	
Electro Products Laboratories	44
Electro-Mec	77
Div. of Waltham Precision Instrument Co., Inc.	
Elgin Micronics	50
Div. of Elgin National Watch Co.	
Elgin National Watch Co.	Cover 2
Electronics Division-Advance Relays	
G	
General Electric Co.	69
Globe Industries, Inc.	65
Graphic Systems	80
Guardian Electric Manufacturing Co.	16
H	
Haveg Industries, Inc.	56
Taunton Div. (Havelex)	
Haydon Switch, Inc.	15
Heinemann Electric Co.	5
Heinze Electric Co.	21
Hoffman Electronics Corp.	8
I	
Industrial Timer Corp.	7
Insco	74
Div. of Barry Wright Corp.	
J	
Julie Research Laboratories	22
K	
Kearfott Division	47, 49, 51
General Precision, Inc.	
Kollmorgen Corp.	27
Inland Motor Corp. of Va.	

ADVERTISERS' INDEX

ADVERTISERS	PAGE
KOLLSMAN MOTOR CORP.	70
L	
LIONEL ELECTRONICS LABORATORIES *Div. of The Lionel Corp.*	78
LITTON SYSTEMS, INC. *Div. of Litton Industries*	19, 57
M	
METALS & CONTROLS CORP. *Div. of Texas Instrument Co.*	64
MINIATURE PRECISION BEARINGS, INC.	41
MODEL ENGINEERING & MANUFACTURING CORP.	81
MUELLER ELECTRIC CO.	65
N	
NON-LINEAR SYSTEMS, INC.	2
O	
OHIO CARBON CO., THE	68
P	
PACE CONTROLS CORP.	53
PACE ENGINEERING CO.	66
PERFECTION MICA CO. *Magnetic Shield Div.*	62
PHILBRICK, GEORGE A., RESEARCHES, INC.	52
POTTER & BRUMFIELD *Div. of American Machine & Foundry Co.*	4
R	
RF PRODUCTS *Div. of Amphenol-Borg Electronics*	63
REEVES INSTRUMENT CORP.	73
REVCO, INC.	74
ROTIFORM CO., THE	65
S	
SEL-REX CORP.	56
SIERRA ENGINEERING CO.	80
SIGMUND COHN CORP.	55
SKINNER PRECISION INDUSTRIES, INC. *Skinner Electric Valve Div.*	17, 18
SOUTHWEST PRODUCTS CO.	76
STREETER-AMET CO.	69
T	
TECHNICAL WIRE PRODUCTS, INC.	59
TECHNO-COMPONENTS CORP.	60
TECHNOLOGY INSTRUMENT CORP. OF ACTON	44
TEN BOSCH, M., INC.	30
U	
UCINITE CO., THE *Div. of United-Carr Fastener Corp.*	48
UNIMAX SWITCH DIV. *W. L. Maxson Corp.*	25
V	
VAP-AIR HEATING CORP. *Vap-Air Div.*	11
VEEDER-ROOT, INC.	42
W	
WAKEFIELD ENGINEERING, INC.	31
WARD LEONARD ELECTRIC CO.	58

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The way you beat this problem is to check the pressure switch under every known operating requirement . . . not just in a vacuum, or 0% humidity or just at sea level, for instance.

Take Model 6621 shown at right that can do so many jobs . . . operate warning lights, measure fuel and oil pressures, actuate air-conditioning for electronic gear. This model, in ranges from 5 to 1000 psig, operates between −65 to 275°F, withstands shock up to 100 g's and vibration to 2000 cps. It is only 1 1/16" diameter by 2½" and weighs but two ounces.

Copy us. Test it yourself for six weeks under all the requirements of your job.

Or save six weeks by checking our own test data on a full line of pressure switches for the type that meets your needs best. Call Mr. Charles Colt at Consolidated Controls, Bethel, Conn. Phone Pioneer 3-6721, DDD Code 203.

Inches of Water to Hundreds of Atmospheres

Model 6621 shown above is one of more than 300 pressure switches available from Consolidated Controls for missile, aircraft and nuclear applications. Working pressures range from 10" of water to 10,000 psi at ambient temperatures from −65°F to 1000°F. Standard models for

- high vibration
- differential pressures
- hydraulic
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ADVERTISING PRODUCT INDEX

Product	Page
Amplifiers, control	44
Amplifiers, dc, 100 watt	27
Amplifiers, servo	30, 67
Amplifiers, solid state	52
Analyzer, gear	65
Bearings, ball miniature	41
Bearings, spherical	73
Carbon graphite	68
Choppers	36
Chains and sprockets	80
Clips	72
Components, digital computer	19
Components, guidance	81
Components, microwave	81
Connectors, electrical	21
Contacts	66
Control systems	10
Control systems, temperature	11
Counters, magnetic	42
Counters, mechanical	Cover 4
Differentials, computing	73
Digital recording voltmeter	2
Display boards	80
Drives, package	44
Electrical connectors	21
Employment	57
Encoders, shaft	19
Environmental cabinets, temp.	74
Environmental control	68
Explosion proof valves	17, 18
Filters, frequency	Cover 3
Gears, precision	75
Indicators, angle	47
Indicators, elapsed time	50
Insulating materials	56
Mechanical counters	Cover 4
Motors, ac, dc	23
Motors, digital	53
Motors, gear	65
Motors, servo	33, 72
Motors, shaded-pole	69
Motors, synchronous	70
Motors, universal	19
Parts, precious metal	64
Plating, gold	56
Potentiometers, low torque film	1
Potentiometers, trimming	60
Power supplies	22, 52
Precious metal parts	64
Relays	Cover 2, 10,71
Relays, overload	5
Relays, power	16
Resistors, power	58
Scales, electronic	69
Seals, pressure strips	59
Semiconductor cooling	31
Shields, magnetic	62
Slip-ring assemblies	81
Solenoid valves	17, 18
Speed reducer	74
Spherical bearings	73
Supplies, power	22, 52
Switches	10, 66
Switches, co-axial	63
Switches, lever actuated	25
Switches, pressure	16, 26, 82
Switches, uniplane	48
Tachometers	51
Tapes, pressure-sensitive	55
Test equipment	19, 81
Thermostats, mercury type	11
Timers, recycling	7
Transducer, pressure	66
Transducer, variable reluctance	65
Wire, electroplated	55

INDEX
Page
44
27
30, 67
52
65
41
73
68
36
80
72
19
81
81
21
66
10
11
42
Cover 4
73
2
80
44
21
57
19
74
68
7, 18
Cover 3
75
47
50
56
Cover 4
23
53
65
3, 72
69
70
19
64
56
1
60
, 52
64
0,71
5
16
58
69
59
31
62
81
, 18
74
73
, 52
, 66
63
25
82
48
51
55
81
11
7
66
65
55
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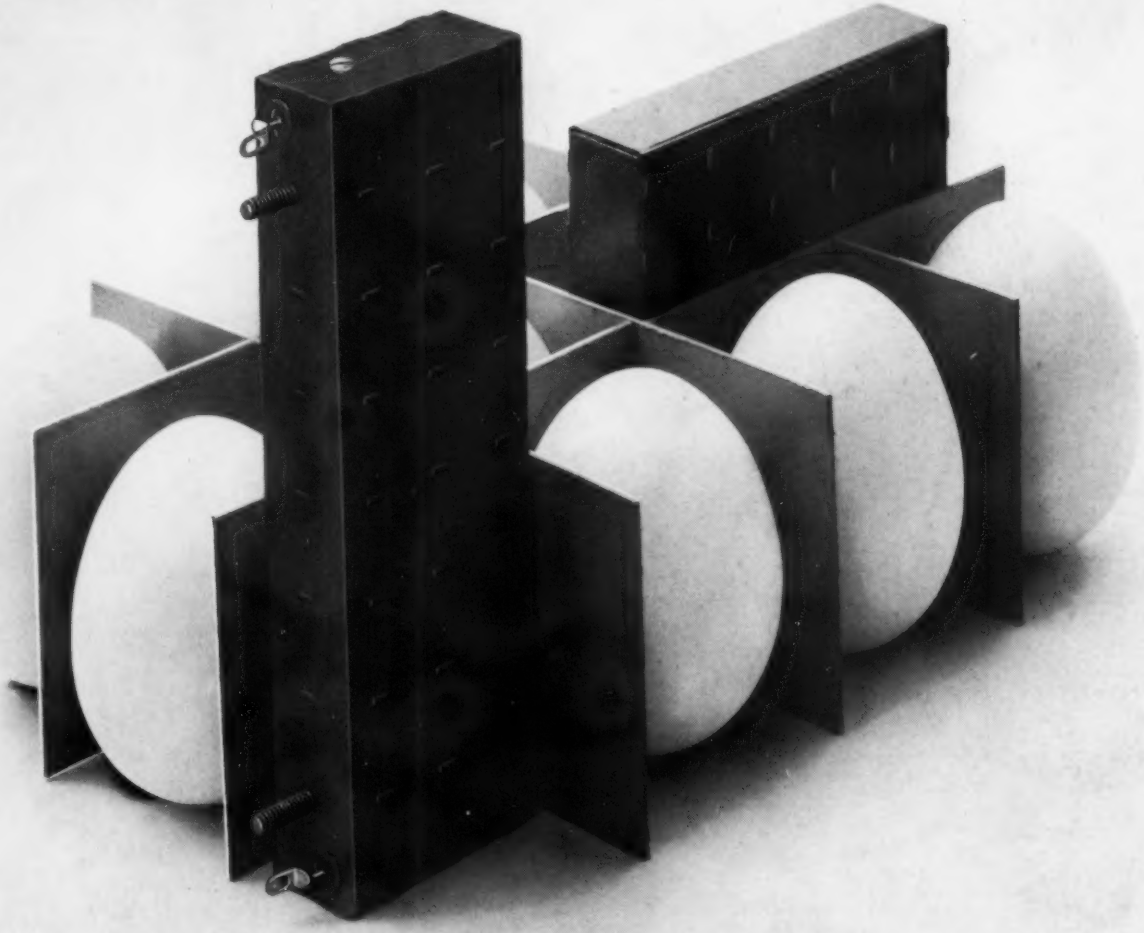

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. . . Unscramble Problems with Daven LC Egg Crate Filters

Daven has taken a fresh approach to some brand new problems — how to build peak reliability, small size and light weight into filters for many critical applications, including underwater sound equipment and command-destruct devices for missiles. Here, for instance, are two typical specs:

(a) one filter with a center frequency of 5.0 Mc ± 5 KC, 3 db bandwidth of 200 KC, 60 db bandwidth of 480 KC, ripple of less than .5 db;

(b) another filter has a center frequency of 26 Mc ± 26 KC, 3 db bandwidth of 560 KC, 60 db bandwidth of 1,700 KC, ripple of less than .5 db.

These are ideal for pulse-type circuits or those with uniform phase characteristics and, as is the case with all Daven filters, can be pre-tuned in the circuit to eliminate additional adjustment during assembly.

Daven supplies filters which are excellent for medium and wide bandwidths. Wherever undercoupled response is permitted, bandwidths as narrow as .5% can be supplied. All are available in quantity, identical to the prototype.

For complete assistance in low audio range filters, as well as filters with special high frequency characteristics, send details of your specific application.

THE DAVEN COMPANY, Livingston, New Jersey

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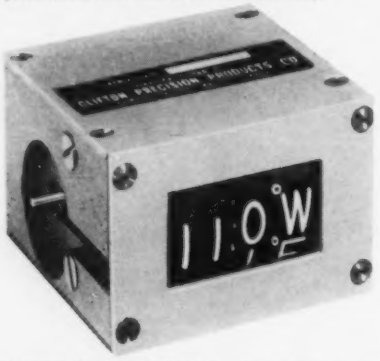
COUNTERS

with LARGEST numerals (1/4")

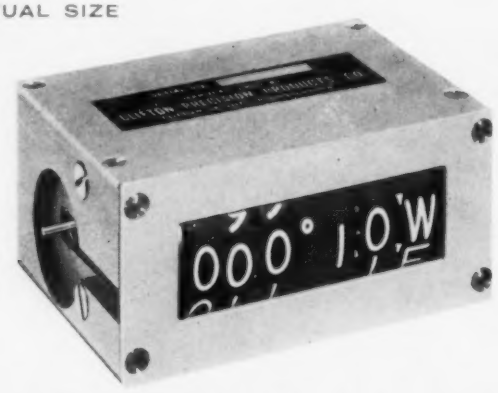
in the LEAST panel space

LATITUDE COUNTER 39100000—This miniature latitude counter provides latitude indications adding from 00°00'N to 89°59' N and stop in north presentation. With reversed rotation of input shaft north flag (N) switches to south (S) at 00°00' and presentation then adds to 89°59'S and stop.

ALL COUNTERS
SHOWN ACTUAL SIZE



MAGNETIC VARIATION COUNTER 39300000—This miniature magnetic variation counter provides variation indications adding from 000° to 179°W in west presentation. With continued rotation of input shaft in same direction the west flag (W) switches to east (E) and the presentation then subtracts from 179°E to 000°E. Continued rotation shifts the flag back to west again and presentation is added at 000°W to 179°W. Reverse rotation reverses presentation.



LONGITUDE COUNTER 39200000—This miniature longitude counter provides longitudinal indications adding from 000°00' to 179°59'W in west presentation. With continued rotation of input shaft in same direction the west flag (W) switches to (E) and the presentation then subtracts from 179°59'E to 000°00'E. Continued rotation shifts flag back to west again and the presentation is added at 000°00'W to 179°59'W. Reverse rotation reverses presentation.

SPECIFICATIONS

Miniature Mechanical Counters
Latitude, Longitude and Magnetic Variation Series

INPUT SPEED
800 r.p.m. maximum intermittent;
500 r.p.m. continuous

INPUT TORQUE
1.0 inches-ounces maximum at 25°C

CROSSOVER TORQUE
3.0 inches-ounces maximum at 25°C

MATERIALS
Housing: Black anodized aluminum
Drums: Diallyl Phthalate black
Internal parts and input shaft:
Stainless steel

BEARINGS
ABEC 5 stainless steel ball bearings on all shafts

WEIGHT
4 ounces maximum

ROTATION
Reversible with continuous one way rotation. Fifteen revolutions of input shaft changes readings by 2°40' for the latitude and longitude counters. Fifteen revolutions of input shaft changes reading by 160° for the variation counter.

NUMERAL SIZE
.250" high: .031" line width. White characters on black. 1,000 diameter wheels per MS-33558 (ASG).

A unique crossover mechanism (on which CPPC patent is pending) has enabled CPPC to produce precision mechanical counters with no shutter and a single set of wheels. The resultant counters are of a minimum size (less than 2.5 square inches of panel space required), and yet allow the largest numerals, ¼" high, which we have been able to discover in counters of this size and accuracy.

These counters were designed and manufactured by us for our own miniature navigation computers. They meet requirements of MIL-E-5272 and MIL-T-5422.

For information phone or write: Area 215 MAdison 2-1000, TWX LNSDWN, Pa. 1122 (U) —or our Representatives.

Engineers: Join the leader in the electromechanical components field. Write David D. Brown, Director of Personnel.

CLIFTON PRECISION PRODUCTS CO., INC.

cppc SYSTEMS DIVISION

Clifton Heights, Pennsylvania

CIRCLE NO. 64 ON INQUIRY CARD